SENIOR SECONDARY COURSE

313

CHEMISTRY

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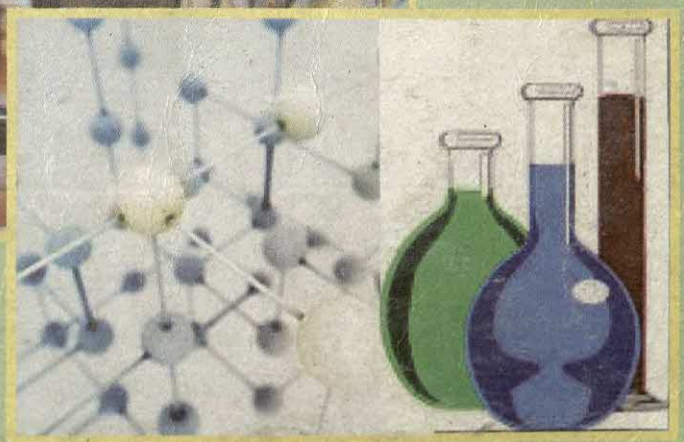

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NATIONAL INSTITUTE OF OPEN SCHOOLING

SENIOR SECONDARY COURSE

CHEMISTRY

3

(OPTIONAL MODULES)

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FOREWARD

Dear Learner,

We are very happy that you have joined NIOS and decided to become an Open and Distant Learner.

NIOS has brought out its revised Senior Secondary Course material. This course has been designed in a **modular format** in the sense that the content is divided into different modules. These modules are made up of a number of lessons. The modules are self contained and you can pick up any of the modules first that interests you. However, we would like you to proceed as the modules have been arranged because there are references and cross references to other lessons.

One of the main features of this course is the division of the modules into **core** and **optional** modules. The core modules are compulsory for all learners, but you can choose any **one** of the two optional modules. For example, in Geography, you can pick up either Local Area Planning **or** Tourism Geography; in Business Studies, you can study either Wage Employment in Business **or** Self Employment in Business. Each subject offers two optional modules. The idea is to allow you to study what interests you more even in one particular subject. This is something unique to the NIOS courses of study. You will not find such **choice** elsewhere.

This course is revised on the lines of the guidelines contained in the National Curriculum Framework 2005. We have tried to make the material as **activity based** as possible. We believe that you learn more when you do something with your own hands rather than just passive reading. We have made efforts to keep the **language of the study material simple** to facilitate you to understand the content easily.

The examples that we have chosen and used in the course material are from daily life to enable you to relate easily what is new to what you already know. Through the Self Learning Materials, we are trying to help you to construct your own knowledge so that you learn by understanding and not just by memorising everything.

Another important feature of this learning material is integration of Adolescence Education issues with the learning content. Realising that development of life skills like self awareness, critical thinking, negotiation and communication skills is important, we have used different opportunities to build desirable skills in the lessons.

The study materials developed by NIOS are **self-learning materials**. You are supposed to read and work on your own. Unlike a textbook, you do not need a teacher to tell you what to do.

With our good wishes, start studying, do what you are told to do, attempt all activities, answer the intext questions, check your answers from the answers given, learn each topic well and be a **successful self learner**.

Chairman, NIOS

HOW TO USE THE STUDY MATERIAL

Your learning material has been developed by a team of physics experts in open and distance learning. A consistent format has been developed for self-study. The following points will give you an idea on how to make best use of the print material.

***Title** is an advance organisor and conveys an idea about the contents of the lesson. Reflect on it.*

***Introduction** highlights the contents of the lesson and correlates it with your prior knowledge as well as the natural phenomena in operation in our immediate environment. Read it thoroughly.*

***Objectives** relate the contents to your desired achievements after you have learnt the lesson. Remember these.*

***Content** of the lesson has been divided into sections and sub-sections depending on thematic unity of concepts. Read the text carefully and make notes on the side margin of the page. After completing each section, answer intext questions and solve numerical problems yourself. This will give you an opportunity to check your understanding. You should continue reading a section till such time that you gain mastery over it.*

*At some places you will find some text in **italics and bold.** This indicates that it is important. You must learn them.*

***Solved Examples** will help you to understand the concepts and fix your ideas. In fact, problem solving is an integral part of training in physics. Do them yourself and note the main concept being taught through a particular example.*

***Activities** are simple experiments which you can perform at your home or work place using readily available (low cost) materials. These will help you to understand physics by doing. Do them yourself and correlate your findings with your observations.*

***Intext questions** are based on the concepts discussed in every section. Answer these questions yourself in the space given below the question and then check your answers with the model answers given at the end of the lesson. This will help you to judge your progress. If you are not satisfied with the quality and authenticity of your answers, turn the pages back and study the section again.*

***What have you learnt** is essentially summary of the learning points for quick recapitulation. You may like to add more points in this list.*

***Terminal exercises** in the form of short, long and numerical question will help you to develop a perspective of the subject, if you answer these meticulously. Discuss your responses with your peers or counsellors.*

***Answers to intext questions :** These will help you to know how correctly you have answered the intext questions.*

***Audio:** For understanding difficult or abstract concepts, audio programmes are available on certain content areas. You may listen to these on FM Gyanvani or may buy the CDs from Priced Publication Unit, NIOS*

***Video:** Video programmes on certain elements related to your subject have been made to clarify certain concepts. You may watch these at your study center or may purchase these CDs from Priced Publication Unit, NIOS.*

These are few selected websites that you can access for extended learning.

Studying at a distance requires self-motivation, self-discipline and self-regulation. Therefore you must develop regular study habit. Drawing a daily schedule will help you in this endeavour. You should earmark a well-ventilated and well-lighted space in your home for your study. However, it should not be noisy or distract your concentration from your work.

Overview of the Learning Material

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Module I
Atoms, Molecules and Chemical Arithmatics

1. Mole Concept
2. Chemical Arithmatics

Module II
Atomic Structure and Chemical Bonding

3. Atomic structure
4. Periodic table and atomic properties
5. Chemical Bonding

Module III
States of matter

6. The Gaseous State
7. The Liquid State
8. The Solid State
9. Solutions
10. Colloids

Module IV
Chemical Energetics

11. Chemical Thermodynamics
12. Spontaneity of Chemical Reactions

Module V
Chemical Dynamics

13. Chemical Equilibrium
14. Ionic Equilibrium
15. Electro Chemistry
16. Chemical Kinetics
17. Adsorption and Catalysis

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Module - VI
Chemistry of Elements

18. Occurrence and extraction of metals
19. Hydrogen and s-Block Elements
20. General Characteristics of the p-block Elements
21. p-block Elements and their Compounds – I
22. p-block Elements and their Compounds - II
23. d-Block and f-Block Elements
24. Coordination Compounds

Module - VII
Chemistry of Organic Compounds

25. Nomenclature and General Principles
26. Hydrocarbons
27. Compounds of Carbon Containing Halogens (Haloalkanes and Haloarenes)
28. Alcohols, Phenols and Ethers
29. Aldehydes, Ketones and Carboxylic Acids
30. Compounds of Carbon Containing Nitrogen
31. Biomolecules

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Module - VIIIA
Environmental Chemistry

32. Environmental Concerns
33. Air Pollution
34. Water Pollution
35. Heavy Metal Contamination
36. Radioactive Pollution

Module - VIIIB
Chemistry and Industy

32. Petrochemicals
33. Polymers
34. Dyes, Paints and Pigments
35. Drugs and Medicines
36. Building Materials

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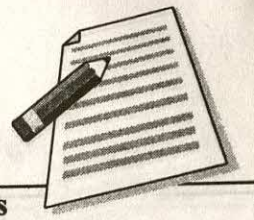
MODULE - VIIIA
ENVIRONMENTAL CHEMISTRY

32. Environmental Concerns
33. Air Pollution
34. Water Pollution
35. Heavy Metal Contamination
36. Radioactive Pollution



Notes

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ENVIRONMENTAL CONCERNS

You know that the Earth is the only planet which supports life. The earth has just the right kind of conditions of temperature range, air, water, soil for supporting life and is protected from harmful rays from the outer space by the ozone layer. With progressive increase in human population and human activities, the quality of air, water, soil and other natural sources get degraded and become unfit for use by organisms. It causes unwanted effects. In this lesson you shall learn about the sources of pollutants and their effects on environment. Thus the environmental pollution in many ways threaten the existence of many organisms including human being on the earth. Therefore, any threat of degradation or damage to the environment should be a matter of concern.

Objectives

After reading this lesson you will be able to :

- define environment and biosphere;
- differentiate the varions environmental segments;
- explain nature of threats to environment;
- define pollutants and its types;
- list sources of pollutants and
- explain the effects of pollutants on environment, organisms and humans in particular.

32.1 Components of Environment

Different organisms live in different types of surroundings such as air, water and soil. Different kinds of living organisms share these surroundings. The surroundings are the "environment" of an organism.

Environment has two components

(i) physical or abiotic (non-living) components and

(ii) living or biotic components.

Abiotic components of environment are air, water, soil, energy radiation, etc. **Biotic components** of environment are microbes (such as bacteria, algae and fungi), plants, animals, etc.

Environment is the sum total of living and non living components surrounding an organism.

Environment consists of four segments such as

(i) Biosphere (ii) Atmosphere (iii) Hydrosphere, and (iv) Lithosphere

Biosphere : All the parts of the earth are not suitable for survival of organisms. Some parts are too hot or very cold to support life.

The part of earth on which organisms can survive and reproduce is called biosphere.

Survival of organisms depend upon a delicate balance between themselves and with the various components of the environment. Any disturbance, damage or adverse change in the quality of environment poses a threat to the survival and well being of organisms. Therefore, any threat of degradation or damage to environment should be a cause of concern to all of us.

Atmosphere : Atmosphere is the only place where free oxygen and water vapour exist.

Atmosphere is a thin layer of air (mixture of gases) around the earth which is a great source to all living organisms.

Hydrosphere : Water plays an important role in the biosphere, without it life is impossible.

Hydrosphere is the part of earth on which all types of water resources exists, viz., oceans, seas, rivers, lakes, glaciers, ice caps, ground water, etc.

Lithosphere : Soil is a part of lithosphere which supports life.

Lithosphere is the part of the earth where all types of minerals, metals, organic matters, rocks, soils, etc. exist

32.2 Threats to Environment

Environment gets damaged due to several reasons. The damage may be in the small area or may affect a much larger area and its ill-effects may by felt all over the globe.

The environmental damages may be broadly classified as:

(i) Regional, and (ii) Global

Those environmental damages which affect the living and non-living things locally over a small area are termed as *regional environmental damages.*

The environmental damages which affect the living and non living things globally or wider part of the earth are called *global environmental damages.*

Some examples of both regional and global environmental damages are mentioned below.

Regional Environmental Damages :

(i) The vehicular combustion of fossil fuels (petrol and diesel) releases carbon monoxide (CO), carbon dioxide (CO_2) and sulphur dioxide (SO_2) into the atmosphere. SO_2 combines with water droplets in the atmosphere to form sulphuric acid (H_2SO_4). Sulphuric acid causes acid rain in the atmosphere and damages the environment over a small area.

The environmental effects of acid rain include:

(a) leaching of nutrients from soil and

(b) corrosion of basic material such as limestone and marble.

(ii) Pesticides, especially DDT (dichloro diphenyl trichloro-ethane) and dieldrin used to control mosquitoes and agricultural pests have become serious pollutants of air water and soil. Being long lasting (do not break down to other molecules that is non-biodegradable) under natural conditions. The pesticides remain in the soil and their amount goes on increasing in soil and water with successive applications. Their ill effects damage the environment locally.

(iii) Various industries like steel, non ferrous metals, fertilizers and petroleum are sources of toxic pollutants like lead (Pb), cadmium (Cd), zinc (Zn), arsenic (As). nickel (Ni) and mercury (Hg). These toxic metals pose a great threat to the local environment.

(iv) The industrial waste contains suspended matter, dissolved solids, toxic metals, chemicals, strong acids, alkalies, oils, dyes, etc. These substances deplete the dissolved oxygen of water and impair the biological activities, finally destroying aquatic life.

Two instances of environmental hazards due to pollution in our country are quoted below:

(i) The effluents like SO_2, of Mathura refinery are posing a very serious threat to Taj Mahal.

(ii) The mishap which took place due to leakage of MIC (methyl iso cyanate) on 2nd

December 1984 from factories of Union Carbide at Bhopal killed thousands of people and have affected the health of those exposed to MIC.

Global Environmental Damages

Some example of global damages are discuss below.

(i) Chloroflouro carbons (CFCs), used as refrigerants, and various kinds of sprays or sols (eg. perfumes, air freshner, etc.). CFCs cause ozone holes in the ozone layer. Ozone hole refer to depletion of ozone molecules in the ozone layer due to the reacton of CFCs.The holes in the ozone layer appear elsewhere and not where these chemicals are used.

(ii) More ultraviolet radiations reach the earth through the ozone holes and the reflected radiations from the earth are absorbed by CO_2 water vapour, etc. The traped radiations release more and more heat resulting in the phenomenon of **Global Warming.** This effect is also known as **Green House Effect.**

Global environment damage affects quality of environment over a much larger area and is not localised to the area where the damage is initiated. Global warming will cause ill

effects and are not confined to the area causing the damage. It causes wide range of effects like melting of glaciers, polar caps, rise in water level of sea and flooding of costal plains, etc.

Intext Questions 32.1

1. Define environment.

   .....

2. What are the two components of environment?

   .....

3. List three biotic components?

   .....

4. Name two common toxic metals which pollute water.

   .....

5. How do CFCs affect the ozone layer?

   .....

6. What are the different segments of environment?

   .....

32.3 Pollution

In ancient times human settlements began and flourished along river banks as rivers provided them basic facilities. Growth of population forced people to move to other places. They started utilising natural resources such as trees and soil (mud) to build shelters. More waste material started collecting at places they inhabited. Humans themselves created conditions for disposal of waste (sanitation). Humans then started industries to manufacture goods for their own comforts. Pesticides and chemical fertilisers were manufactured to grow more food for the growing demand by population. Industries also generated wastes, which ultimately finds its way to water sources. Pesticides and chemicals were washed into natural water bodies such as sea, river, lakes and ponds and affected the aquatic organisms. Supply of potable (safe for drinking) water diminished. All this badly affects life of organism including humans. All such waste generated through human activities and spoiling the natural environment is termed as **pollutants**. Damaging the natural environment by pollutants is termed as **pollution.**

Pollution refers to deterioration or unclean objectionable conditions in the quality of natural resources such as air, water and soil because of the action or presence of unwanted substances beyond a certain limit.

32.4 Pollutants

Pollutants are the substances or effect introduced into the environment in significant amounts in solid, semi solid, liquid gas or sub molecular particle form which has a detrimental (bad) effect on the environment.

The pollutants may be classified in the following ways (Fig.32.1).

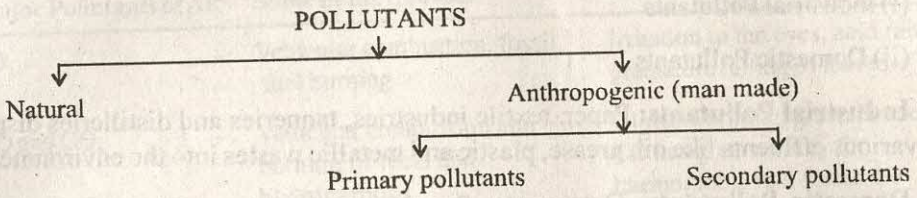

Fig. 32.1 : *Classification of pollutants*

32.4.1 Natural Pollutants

There can be several natural sources which are the cause of pollution. Some of them are listed below :

(i) Fires in forests may be caused when lightening strikes the trees. Burning of tree produces a lot of CO_2 which is released to the atmosphere.

(ii) Soil erosion increases suspended particulate matter and dust in air. These may even enter water bodies as they are washed down by rain or natural water falls.

(iii) Volcanic eruptions also add pollutants like SO_2 and solid particles to the environment.

(iv) Volatile organic compounds from leaves, trees and dead animals naturally enter the atmosphere.

(v) Natural radioactivity and the other natural pollutants have been entering the environment since ages. (But the low level of pollution has rarely endangered lives of organisms).

32.4.2 Anthropogenic Pollutants

Increased human activities releases a large amount of pollutants to the environment and poses a threat to the human life. Pollutants added to the environment through human activities are termed *anthropogenic pollutants*. These are of two kinds.

(i) **Primary pollutants:** Primary pollutants are added directly in a harmful form to the atmosphere. eg CO_2 and CO from burning of fossil fuel; SO_2 and oxides of nitrogen from vehicular combustion, thermal power stations, etc.

(ii) **Secondary Pollutants:** Secondary pollutants are the products of reaction between the primary pollutants and normal environmental constituents.

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

Thus, SO_2 a primary pollutant which reacts with oxygen of air to give SO_3. Further, SO_3 reacts with water vapour present in the atmosphere and forms H_2SO_4. Thus SO_3 and H_2SO_4 are secondary pollutants.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

$$2NO + O_2 \longrightarrow 2NO_2$$

Nitric oxide (NO), a primary pollutant reacts with oxygen to give NO_2 which is a secondary pollutant.

Notes

Depending on the sources, anthropogenic pollutants may be classified further into

(i) Industrial Pollutants

(ii) Domestic Pollutants

(i) **Industrial Pollutants:** Paper, textile industries, tanneries and distilleries dispose various effluents like oil, grease, plastic and metallic wastes into the environment.

(ii) **Domestic Pollutants:** Detergents, fluoride toothpastes, edible colours, food flavouring agents, polythene bags and wrappers find their way into the environment as pollutants. Methane is produced in cattle stomach and in stagnant paddy fields is also a domestic pollutant.

Intext Questions 32.2

1. Define a pollutant

2. Name two sources of natural pollution.

3. Define a secondary pollutant.

4. What do you mean by environmental pollution?

32.5 Sources of Pollutants

Many of the pollutants in our environment have natural as well as human related origins. For example, the natural origin of pollutants includes the release of sulphur dioxide (SO_2) from volcanic eruptions, erosion of soil by wind and water, dissolved minerals carried on to rivers and ocean by surface run off, etc.

The sources of pollutants are also classified

(i) Stationary and

(ii) Mobile sources

Stationary Sources : The pollutants released from a fixed location or a well defined area is known as stationary source, e.g. smokestacks of power plants, smelters, surface mines, etc.

Mobile Sources : The pollutants released from diffused sources or the sources that move from place to place is termed as a mobile source, e.g. automobiles, buses, aircrafts, ships, trains, etc.

The various pollutants of water, their sources and effects are given in Table 32.1

Notes

Table No. 32.1 : Major Air Pollutants their Sources and Effects

Major Pollutants of Air	Some of the Sources	Some of the Effects
SO_2	Molecular combustion, fossil fuel burning	Irritation to the eyes, acid rain premature falling of leaves
CO and CO_2	Molecular combustion and burning of fuels and hydrocarbons	Global warming, green house effect, CO has great affinity for haemoglobin and forms the carboxy haemoglobin
Smoke, fly ash and soot	Thermal power stations	Respiratory diseases
Lead and mercury	Auto exhaust from gasoline, paints, storage batteries, fossil fuel burning	Affects the nervous system and circulatory system causing nerve and brain damage
CFCs	Refrigerants and aerosol	Kidney damage and ozone depletion.

The various pollutants of water, their sources and effects are summarized in Table No. 32.2

Table 32.2 : Major Water Pollutants their Sources and Effects

Major Pollutants of Water	Some of the Sources	Some of the Effect
Pesticides and insecticides like DDT, BHC	In proper use in agriculture, mosquitos, repellents	Toxic to fishes, poultory birds and mammals
Plastics	Dumps and industries	Kills fishes and animals like cows.
Chlorine compounds	Water disinfection with chlorine, paper and bleaching powder	Fatal for plankton (organisms floating on the surface of industries water), fish farm and others, can cause cancer in humans.
Lead	Leaded gasoline, paints, etc.	Toxic to organisms
Mercury	Natural evaporation and dissolved industrial wastes, fungicides	Highly toxic to humans
Acids	Mine drainage, industrial wastes	Kills organisms
Sediments	Natural erosion, run off from fertilizer and other factories, mining and construction activities.	Reduces ability of water to assimilate oxygen.

The general effects of pollutants are produced due to interactions of pollutants among themselves.

Contamination :
Contaminations refer to the mere presence of undesirable materials to a medium like air, water, soil, etc. making it unfit for a particular use. For example, contamination of air by hazardous exhaust from automobiles. It becomes a pollutant if its concentration exceeds the level which can cause harmful effect.

32.6 Noise Pollution

Any unwanted sound is defined as noise. You know that the noises come from traffic, vehicles, especially at peak hour everyday, loud speakers and building construction work. Industries expose their workers to a high level of noises for long period of work everyday.

Prolonged exposure to high level of noise is harmful. Noise is measured in terms of 'decibel' (db) - a scale expressing intensity of the sound.

A very quiet room has a sound level of 20 db, cars and household gadgets - 70 db while a truck horns produces a noise of 110 db.

Noise has harmful effects on human body. Noise of 70-80 db causes annoyance and irritation. Above this level, breathing rate may be affected, blood vessels may constrict, movement of digestive canal is disturbed, glandular secretions may be affected. Long exposure to high noise levels can impair hearing.

Standards have now been laid down for different areas. Silence zones are the areas 100 meters around hospitals, courts, schools and other institutes. Honking of vehicle horns, cracker bursting, loud speakers and loud voice of hawkers selling their wares is prohibited. The noise level has to be kept within 50 db. Similar restrictions have been laid down for industries and commercial organisations.

Legislative Measures to Prevent Pollution

The best protection of the environment is not to generate pollutants in the first place. Thus, the legislative measures have been introduced to deal specifically with environmental pollution caused by industries. (Table 31.3) The basic feature of the legislative measures is to empower the Central Government to correct differences of policy making and enforcement in the States through action not specifically permitted under earlier laws.

Table 32.3 : Pollution control Legislations in India

Acts	Year
Indian Forest Act	1927
Wildlife Protection Act	1972
The water (Prevention and control of Pollution) Act	1974
The air (Prevention and control of Pollution) Act:	1981
The Environmental (Protection) Act	1986
The National Environmental Tribunal Act	1995

The pollution related laws like the Water Act (1974), Air Act (1981), and the Environmental Protection Act (1995) do not give the right to an individuals to move the court under the environment laws for damages caused to them by pollution. The right has been vested only in the agencies of the State Government.

Intext Questions 32.3

1. Mention one bad effect each of SO_2 and CO on humans.

.....

2. Name one source of each pollutant lead and CFC.

.....

3. Name the two major sources of anthropogenic sources of pollutants in the environment.

.....

4. Give two examples of stationary sources of pollution.

.....

What You Have Learnt

- Surroundings in which we live is our environment.
- There are two components of environment : physical or abiotic and living organisms or biotic
- Pollutants may be defined as substances added to natural surroundings.
- There are two major sources of pollutants - stationary and mobile.
- Pollutants have adverse effects on environment and living organisms.
- SO_2, CO_2, CO, smoke, Pb, Hg, CFC, etc. pollute air. Their sources and effects are varied.
- Pollution in simple words is the unhealthy and harmful condition for living organisms and non-living things.
- Pesticides, plastic, detergents, chlorine, mercury, etc. pollute water and endanger life of aquatic organisms.
- Unwanted sounds are termed as noise. Sounds is measured in decibels. Beyond 70 decibels noise has harmful effects on humans.
- The Government of India has set up various environmental laws and judiciary system to punish the polluters.

Terminal Exercise

1. What is environment?

.....

2. Explain the term anthropogenic pollutants.

.....

3. Write four major pollutants of water, their sources and effects.

.....

4. Differentiate between the Primary and Secondary Pollutants.

.....

5. Name any three legislative measures (Acts) to protect the environment.

.....

Answers to Intext Questions

32.1

1. The air, water, earth and living beings in a joint form is called environment.
2. There are two components of environment namely biotic and abiotic.
3. Living organisms such as plants, animals, microbles, etc.
4. Lead and Mercury.
5. Causes holes in the ozone layer.
6. Atmosphere, biosphere, hydrosphere and lithosphere.

32.2

1. Any substance which is present in its excess concentration such as CO_2, CO, SO_2.
2. Volcenicerruptions and run-off from surface mines.
3. Secondary pollutants are the products of reaction between the primary pollutant and the normal environmental constituents.
4. Environmental pollution is the deterioration or unclean objectionable conditions in the quality of natural resources such as air water and soil because of the action or presence of unwanted substances in undesirable concentration.

32.3

1. Irritation to eyes by SO_2 and difficulty in breathing.
2. Lead from exhaust of automobiles running on gasolive (petrol). CFC from refrigerants.
3. Industrial waste and automobile exhaust
4. Smokestacks of power plants, run-off from surface mines.

Notes

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AIR POLLUTION

Organisms have a close inter-relationship with their immediate environment. Oxygen from air is taken in during respiration and carbon dioxide released into the atmosphere by majority of organisms. The CO_2 is taken up by plants to manufacture food. This harmonious relationship between various organisms and nature has been disrupted by human activities. Intensive agriculture, industrialisation, urbanisation have degraded our physical resources and as a result soil, water and atmosphere have become highly polluted.

In this lesson we will define atmosphere and mention its constituents, discuss sources of air pollution and damage done to plant and animal life by atmospheric pollutatns. We shall also outline measures that can stop further atmospheric pollution.

Objectives

After reading this lesson you will be able to :

- explain the composition of air;
- define air pollution;
- explain respiration, photosynthesis and decay cycle;
- cite examples of major air pollutants;
- recall sources of major air pollutants;
- identify relationship between carbon cycle and oxygen depletion by fossil fuel burning;
- explain nitrogen cycle;
- define greenhouse effect;
- recognize factors causing greenhouse effect;
- explain global warming;
- define ozone layer;
- explain depletion of ozone layer;

- explain acid deposition/acid rain;
- recognise ill effects of carbon monoxide on haemoglobin and
- list measures for reducing air pollution.

33.1 Composition of Air

You know that the atmosphere is a thin layer of air surrounding the earth. It is held around the earth due to gravitational pull of the earth. The air become thin (less dense) as we go higher up from the surface.

Most of the air is present within 50 km from the surface of the earth.

The atmosphere is broadly divided into four distinct zones, for example, troposphere, stratosphere, mesosphere and thermosphere.

Troposphere is the zone where all weather events occur.

Stratosphere is the zone of water vapour and ozone whereas in mesophere low concentrations of ozone is present.

Thermosphere is the zone where the gases are present in highly ionized form.

The temperature variation as we go away from earth is not uniform. It increases or decreases as we go higher from the earth.

The increase of temperature with the increase of altitude is known as **positive lapse rate.**

The decrease in temperature with the increase of altitude is known as **negative lapse rate.**

Positive lapse rate occurs in stratosphere and thermosphere. Negative lapse rate occurs in troposphere and mesosphere.

The composition of clean, dry and unpolluted air remains almost constant. The composition of air remains constant due to various natural cycles like carbon cycle, nitrogen cycle, etc. in nature. Any disturbance in the cycles has a harmful effect on organisms. Natural atmospheric air is made up of gaseous and non-gaseous constituents.

(a) Gaseous: Nitrogen and oxygen make up over 98% of volume of air. Other gases are CO_2, water vapour and inert gases such as argon, neon, krypton, helium, xenon radon and ozone are present in traces. These gases based on their available concertrations in the atmosphere are broadly catagorised as major, minor and traces (Table 33.1)

(b) Non-gaseous : Smoke, dust and salt (through evaporation from the sea) are the non-gaseous constituents of air.

Table 33.1 Composition of Atmosphere

Categories	Gas	Formula	Percent by Volume
Major	Nitrogen	N_2	78.09
	Oxygen	O_2	20.94
	Water vapour	H_2O	0.1 to 5
Minor	Carbon dioxide	CO_2	0.035
Trace	Helium	He	0.00052
	Methane	CH_4	0.00015
	Hydrogen	H_2	0.00005
	Sulphur dioxide	SO_2	0.000002
	Ammonia	NH_3	0.00001
	Carbon monoxide	CO	0.00001
	Nitrogen dioxide	NO_2	0.00001
	Ozone	O_3	Trace

33.2 Carbon Transfer Pathways – Respiration, Photosynthesis and Decay Cycle

There is a delicate balance between various constituents of air. Any disturbance in the concentration of the constituents due to pollution will adversely affect the organisms. For example, carbon is actively cycled between inorganic carbon dioxide and various kinds of organic compounds of which organisms are made up of. It moves from inorganic to organic form through the activity of autotrophs (auto; self; trophos : feed). The plants, synthesize food through photosynthesis are the "producers" in the food chain. The process which releases carbon dioxide into the environment is **respiration.** It is a process indispensible for survival of almost all organisms. Another carbon transfer pathway is decay and decomposition of organic matter brought about by micro organisms.

33.2.1 Respiration

Respiration is a process of exchange of gases between organisms and atmosphere. Atmosphere is a reservoir of oxygen and organisms take in this oxygen for oxdiation of food. Oxidation of food liberates energy. When oxygen reaches the cell of an organism a series of enzyme catalysed reactions take place in which chemical bonds of glucose are broken, energy in the form of ATP (adenosine triphosphate) is liberated and carbon dioxide is released. Carbon dioxide goes back into the atmosphere. (Fig. 32.1) Thus a considerable amount of carbon dioxide is returned to the atmosphere through respiratory activity of organisms.

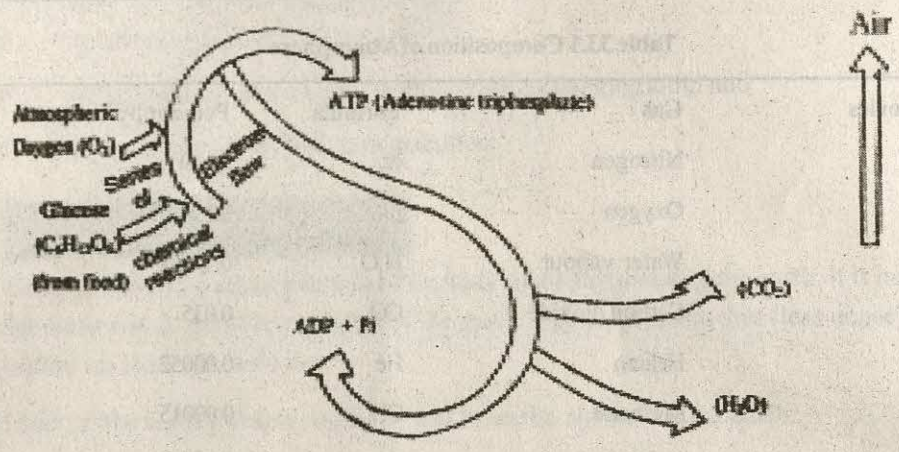


Fig. 33.1 : *Cellular Respiration*

Fig. 33.1 shows cellular respiration in which oxygen oxidises glucose through a series of chemical reactions and an electron transport chain. Energy is released in the form of several molecules of ATP. The CO_2 is given out and goes into the atmosphere. Some ATP molecules are also used up in the process and break up into ADP (adenosine diphosphate) and Pi (inorganic phosphate).

33.2.2 Photosynthesis

Green plants pick up CO_2 from the atmosphere and water from soil. Leaves of green plants contain a green pigment chlorophyll - the photosynthetic pigment. Leaves trap solar energy from sunlight. Light and the pigment interact and through a series of steps, starch is synthesized by plants and oxygen is liberated. Oxygen moves into the atmosphere (Fig. 33.2). Infact for the first two billion years after living organisms evolved on the earth, there was no oxygen. **Oxygen of the atmosphere resulted from photosynthetic organisms (e.g. plants).** So plants are responsible for providing oxygen on the earth which is so valuable to living organisms.

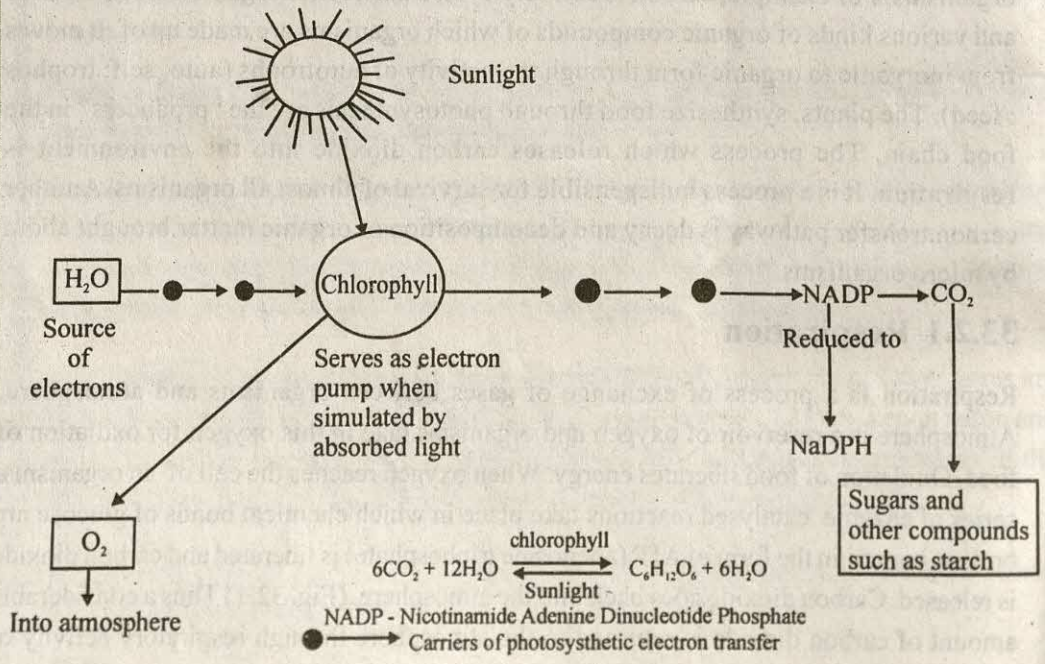


Fig 33.2 : *The Photosynthesis process*

33.2.3 Decay of Organic Matter

Micro organisms like bacteria and fungi bring about decay and decomposition of organic matter left after the death of organisms. Due to microbial (by microorganisms) decomposition of partially digested organic matter and dead organisms, CO_2 is liberated and released into the atmosphere. Thus the decay cycle also adds CO_2 to the atmosphere.

In swamps, paddy (rice) fields and wetlands, anoxic (lack of oxygen) conditions prevail. Methanogenic bacteria convert low molecular weight fatty acids into methane in these areas. These bacteria can also convert CO_2 into CH_4 through a special anaerobic respiratory pathway. An anaerobic pathway is one in which respiration takes place and food is broken down in the absence of O_2 since CO_2 is not available (as in case of aerobic respiration) to autotrophic

Very few organism, such as methanotrophs and nitrifers can oxidise methane and reintroduce carbon into the normal carbon cycle.

33.3 Carbon Cycle in Nature

Carbon cycle is the most important biogeochemical gaseous cycle. Also, carbon is returned to the environment as fast as it is removed.

The richest source of carbon is the ocean where carbon exists as carbonate and bicarbonate ions. Carbon enters the atmosphere mainly as a product of aerobic respiration in the form of CO_2. Volcanic eruptions also release carbon from rocks deep in the earth's crust. CO_2 is taken in by plants for photosynthesis during which they use light energy for reducing CO_2. Plants are, therefore, termed **photoautotrophs.** (photo means light). There are other organisms such as some bacteria which use energy stored in chemical bonds for reducing carbon dioxide to methane. They are termed **Chemoautotrophs.** Photosynthesis, however, is the most important process through which inorganic carbon is converted into organic form.

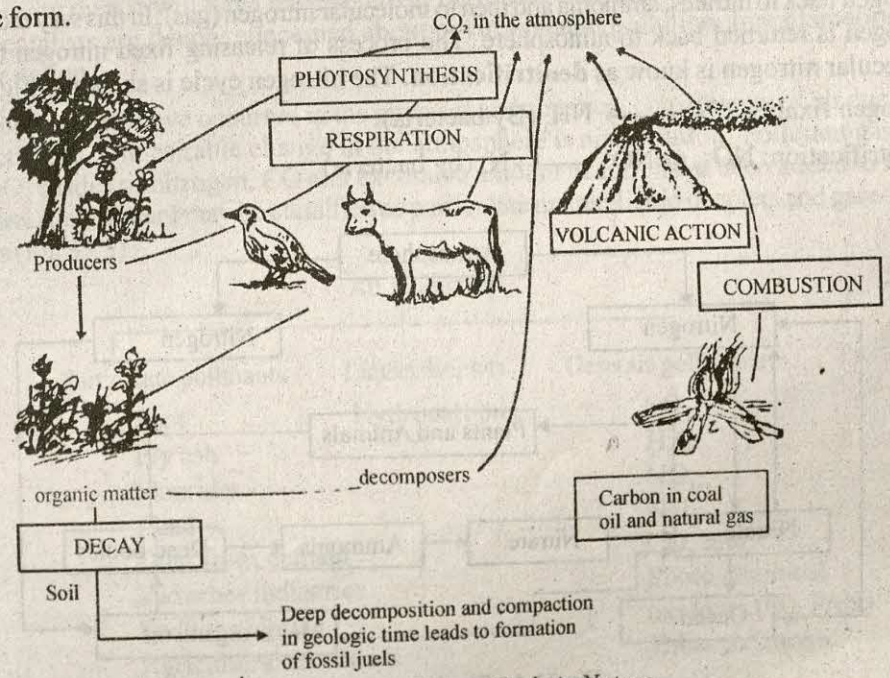


Fig. 33.3 : *The Carbon Cycle in Nature*

When producers and consumers die, decomposers reduce the organic matter of these dead organisms and carbon moves into the soil. Producers, consumers and decomposers add CO_2 to the atmosphere through respiration. Thus a balance in the proportions of O_2 and CO_2 is maintained in nature. (Fig.33.3)

When trees die and fall they get buried in the sediments and over a long geological time they become fossil fuels. Fossil fuels are buried deep in the soil. Carbon in this form remains unavailable till humans deliberately remove it.

33.4 The Nitrogen Cycle

Nitrogen and its compounds are essential for the maintenance of life processes in the biosphere. For example, organisms cannot exist without amino acids, peptides, and proteins, all of which are organic molecules containing nitrogen.

Nitrogen is the most abundant gas (about 78% of the atmosphere), however, plants cannot use free nitrogen (N_2) directly. Plants, algae and bacteria take up inorganic nitrogen either as the nitrate ion (NO_3^-) or the ammonium ion (NH_4^+) from the environment and use it to build their own protein molecules i.e. organic nitrogen . Organic nitrogen is consumed by animals and human beings to build their bodies.

Nitrogen is a relatively inert element and there are few processes that convert the stabilized nitrogen to available nitrogen compounds. Nitrogen gas in the atmosphere is transformed by lightning or bacterial uptake to nitrates or ammonia. In natural process the nitrogen-fixing bacteria (some blue green bacteria) have a highly specialized ability to "**fix**" nitrogen i.e. they change it to less mobile, more useful forms by combining it with hydrogen to make ammonia (NH_3). This is called **Nitrogen fixation.** In this form the nitrogen is used up by plants and algae. They convert inorganic nitrogen compounds into organic compounds and nitrogen becomes available. Through ecological food chains organic nitrogen enter into other living organisms including humans and animals.

When organisms die, other bacteria are able to convert the organic compounds containing nitrogen back to nitrates, ammonia and then to molecular nitrogen (gas). In this way molecular nitrogen is returned back to atmosphere. The process of releasing fixed nitrogen back to molecular nitrogen is know as **denitrification**. The nitrogen cycle is shown in Fig 33.4.

Nitrogen fixation : $N_2 \longrightarrow NH_3$ (By bacteria)

Denitrification: NO^-_3 or $NO^-_2 \longrightarrow N_2$ (by bacteria)

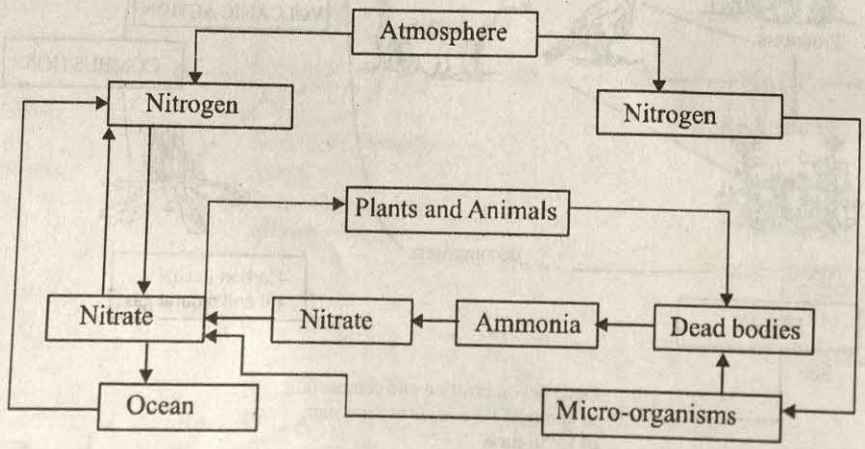


Fig.33.4 : *The Nitrogen Cycle*

Intext Questions 33.1

1. Which gas is present in the maximum amount in the atmosphere?
   .....
2. Name any two major constituents of air.
   .....
3. Which organisms are called autotrophs and why?
   .....
4. Name the food constituent which is broken down during respiration to liberate energy and carbon dioxide.
   .....
5. What is the green photosynthetic pigment present in plants?
   .....
6. How does carbon get into the enviromnent from dead organic matter?
   .....
7. Are humans producers or consumers?
   .....
8. Name two physical phenomena by which carbon is fixed in the nature.
   .....
9. Name the atmospheric layer where ozone is mainly available.
   .....

33.5 Air Pollution

You have just learnt how nature has its own means of using up and getting back its components such as CO_2, O_2 and N_2. If the balance of CO_2, O_2 or N_2 is disturbed by human activity then it will have adverse affect on life on the earth. Now you know why environmentalists are deeply concerned about environmental pollution, tree plantations and afforestation.

Undesirable changes have occurred in the physical and chemical constituents of air due to human activities. Undesirable change in the atmosphere is air pollution. Pollutant gases such as SO_2 oxides of nitrogen, CO and excessive amount of CO_2 have been added to the atmosphere. Air pollutant may be classified as particulate matter, liquid droplets and gaseous pollutants (Fig 33.5) :

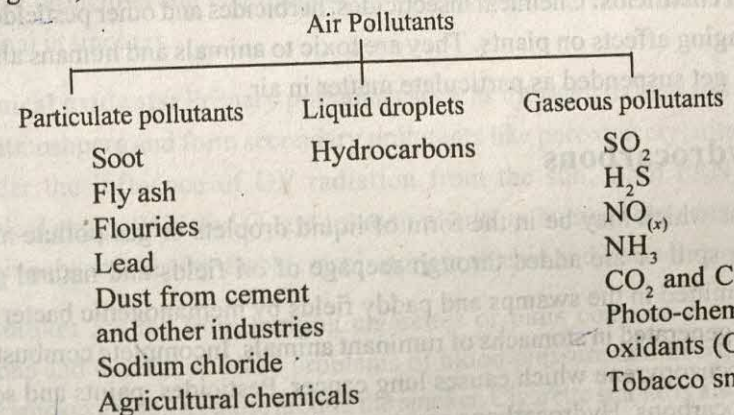


Fig. 33.5 : *Classification and Example of Air pollutants*

33.5.1 Particulate Pollutants

Particulate pollutants such as soot and fly ash are released by various industries as by products of industrial processes. They are blown away by wind when they come out of the chimneys and other outlets of industries and mix with air.

Suspended particulate matter is also emitted by exhaust of polluting diesel vehicles and ill managed coal fired power plants. In nature, forest fires, wind erosion and volcanic eruptions add suspended particulate matter into air. Examples of particulate pollutants are soot, flyash from thermal power plants, cement dust, petrocoke from petroleum refineries. Some of the particulate pollutants are discussed in detail below:

Fluoride: Aluminium, steel and electrochemical plants, blast furnaces, brick kilns, coal combustion, tile and glass etching factories add fluoride particles which settle on vegetation. They burn tips of leaves and when cattle eat the vegetation they suffer from fluorosis resulting in loss of teeth, weight and lameness. Humans also suffer from fluorosis. Volcanoes also release fluorides which form gaseous as well as particulate pollutant.

Lead: Lead particles come into air from automobile exhausts. Lead is used as an antiknock agent in automobile gasoline which contains tetraethyl lead. Paint, ceramic and pesticide industries also add lead particles to the atmosphere. Manufacture of lead storage battries and recycling of discarded battries add to lead pollution. Lead interferes with development of red blood corpuscles and causes anaemia (lack of haemoglobin - the oxygen carrying pigment of blood). Lead is a cumulative poison and prolonged exposure even in low concentration may damage kidneys and liver.

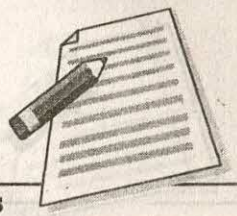
Dust: Particulate matter less than 10 microns in size is dust. It reaches lungs, deposits along the respiratory tract and causes asthma or even lung cancer. Dust from stone crushers is another example of particular pollutant.

Sodium chloride: Sodium chloride is used to remove snow in winter and remains in the enviromnent. Some sodium chloride is also added to the environment when waves of the sea spray it. Excess sodium chloride has been found to cause defoliation (leaf falling), suppression of flowering and breaking of terminal shoots of apple.

Agricultural chemicals: Chemical insecticides, herbicides and other pesticides are known to have damaging effects on plants. They are toxic to animals and humans also. Residues of pesticides get suspended as particulate matter in air.

33.5.2 Hydrocarbons

Hydrocarbons which may be in the form of liquid droplets or gas pollute air. As liquid droplets they spill or are added through seepage of oil fields and natural gas leakage. Methane is emitted in the swamps and paddy fields by methanogenic bacteria. Methane (CH_4) is also generated in stomachs of ruminant animals. Incomplete combustion of fuels release 3, 4 benzopyrene which causes lung cancer. Pesticides, paints and solvents also release hydrocarbons. Hydrocarbons are a source of photochemical smog.



33.5.3 Gaseous Pollutants

SO_2, CO_2, nitrogen oxides are commonly added to the air by human activities. Excess of these have very serious damaging effects on the physical environment as well as on humans.

SO_2 and H_2S : These are released into atmosphere through smelting of ores containing sulphur, manufacture of H_2SO_4 petroleum refining, combustion of fossil fuels, paper making, burning of sulphur containing refuse and in nature through volcanic eruptions. Plants exposed to SO_2 and H_2S show defoliation (leaves falling off) and reduced growth.

In humans, SO_2 pollution causes headache, vomiting, irritation of eye and respiratory passages. SO_2 reacts with water to form H_2SO_4 which is washed down as acid rain about \vhich you shall study later in the chapter.

Nitrogen Oxides: Anaerobic breakdown of nitrogenous compounds by bacteria is the natural source of nitrogen oxides. Burning fossil fuel also releases them. Power generators, automobile exhausts, explosives and nitrogenous fertilizer industries and the other anthropogenic sources produce nitrogen oxides.

NO_2: causes early dropping off of leaves and fruits in plants. Nitrogen oxides are one source of photochemical smog, acid deposition and greenhouse effect. .

CO_2 and CO : Combustion of oil, gas, coal and wood releases CO_2 in the atmosphere. CO is released chiefly from gasoline engines and burning of coal in defective furnaces. Motor vehicles with internal combustion engines emit high levels of CO and hydrocarbons. Excess of CO_2 can cause global warming, CO causes photochemical smog and has a fatal effect when inhaled by humans.

CO poisoning: CO has a high affinity for haemoglobin. It combines with the blood pigment haemoglobin to form carboxyhaemoglobin. The normal function of haemoglobin is to carry O_2. But CO combines with haemoglobin about two hundred times faster than O_2. Tissues do not get oxygen and die due to lack of oxygen. Carboxy haemoglobin is dark red in colour, the victims of CO poisoning have dark red lips. Mild CO poisoning causes lung disorders like bronchitis and emphysema. CO from cigarette smoke makes haemoglobin non functional in smokers.

Photochemical oxidants: Primary pollutants such as nitrogen oxides and hydrocarbons mix in the atmoshpere and form secondary pollutants like peroxyacetyl nitrate (PAN) and ozone, under the influence of UV radiation from the sun. Both PAN and O_3 form photochemical smog. PAN and O_3 are toxic to plants. In humans they cause irritation of eyes coughing, headache, dry throat, respiratory problems and haemorrhage.

Tobacco smoke: Smoke from burning cigarettes or bidis contains nicotine, aromatic hydrocarbons and tar. These cause problems of blood pressure and heart, windpipe and lungs in the smoker as well as those around the smoker. Cigarette smoke is also carcinogenic.

The various human and natural activities which introduce air pollutants into the atmosphere are summarised in Table 33.2

Table 33.2 : Common air pollutants, their sources and contribution of Natural and Anthropogenic pollution

Air Pollutants	Some Sources	Emission (% of total)	
		Natural	Anthropogenic
Sulphur oxide (SO_x)	Fossil fuel burning, industry biomass biomass burning, volcanoes, oceans.	50	50
Carbon monoxide (CO)	Incomplete combustion, methane oxidation, transportation, biomass burning, plant metabolism.	91	9
Nitrogen oxide (NO_x)	Fossil fuel burning, lightening, biomass burning, soil microbes.	40	60
Hydrocarbons (HC)	Fossil fuels, industrial processes, evaporation of organic solvents, agricultural burning, plant isoprenes and other biogenics.	84	16
Suspended Particulate Materials (SPM)	Biomass burning, dust, sea salt, biogenic aerosols, gas to particle conversion.	89	11

Intext Questions 33.2

1. What is atmospheric pollution?

.....

2. Name two particulate pollutants.

.....

3. Name two gaseous pollutants?

.....

4. Name one source which causes pollution due to methane.

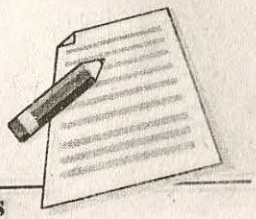
.....

5. Name two air pollutants which form photochemical smog.

.....

33.6 Effects of Excessive Atmospheric Pollutants on Nature (Outdoor Pollution)

You are now familiar with the various atmospheric pollutants. Most of these are products of fuel combustion. These pollutants have been released into atmosphere ever since human first started burning wood and coal. Later on, pollutants are being released into air due to increased industrial activity. The nature has not been able to remove all these pollutants



because much more pollutants are added than the nature can handle to maintain the balance. Therefore, pollutants have now accumulated in the atmosphere to a proportion whereby atmospheric composition of air has been significantly altered. It is the causes of physical phenomena such as photochemical smog, acid rain, ozone depletion, greenhouse effect and global warming. These are damaging to plants, animals and humans.

The figure Fig. no. 33.6 shows the four major effects of atmospheric pollutants. In the diagram, arrows from the pollutant depicts its involvement in the physical phenomenon. The sources of the pollutants are depicted below the names of the pollutants. The four major phenomena are subsequently discussed one by one. They are temperature inversion, photochemical smog, acid rain, greenhouse effect and ozone layer (shield) depletion.

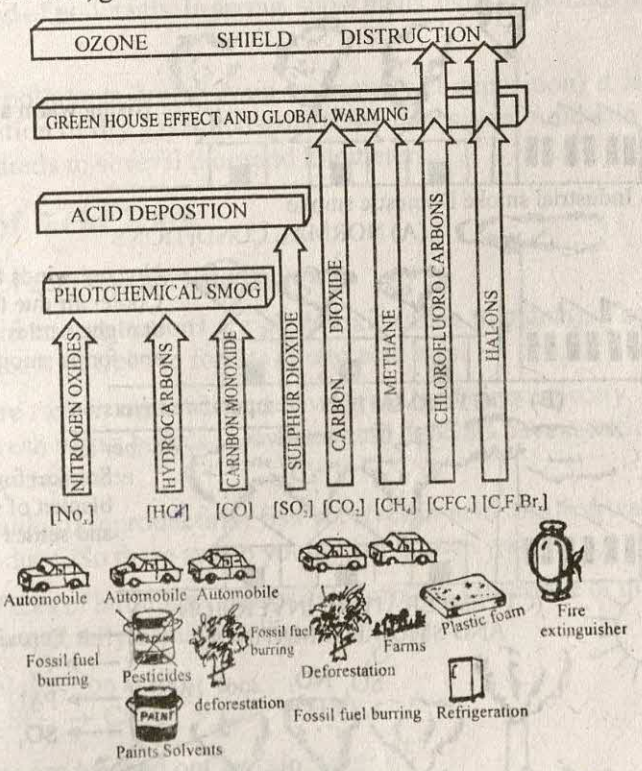


Fig. 33.6 : *Four Major Effects of Atmospheric Pollutants*

33.7 Temperature Inversion and Photochemical Smog

Pollutants like sulphur dioxide which is released while burning sulphur containing fuels (fossil fuels) and particulate matter like soot present in stagnant air masses, get modified in sunlight and form a sheet called photochemical smog.

Smog is a combination of fog, smoke and fumes released by mills and factories, homes and automobiles.

When sunlight falls on stagnant air under low humid conditions in the presence of pollutants such as SO_2 soot, nitrogen oxides and hydrocarbons, photochemical smog is formed (photochemical: chemical reactions in the presence of light). Smog stays close to the ground and reduces visibility and causes irritation.

Photochemical smog is also called *PAN smog* due to the formation of peroxyacetyl nitrate or PAN and ozone which are formed from hydrocarbons and nitrogen oxides in the presence

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of solar radiation. PAN and ozone are called photochemical oxidants. Both of these are toxic irritants to human lungs.

Smog formation is accompanied by ***Temperature inversion or Thermal inversion,*** Temperature inversion causes smog to settle and remain near the ground till wind sweeps it away. Normally, warm air rises up into atmosphere. When a layer of cool air at the ground level is held there by an overlying layer of warm stagnant air. It is called **temperature** or **thermal inversion** (Fig.33.7).

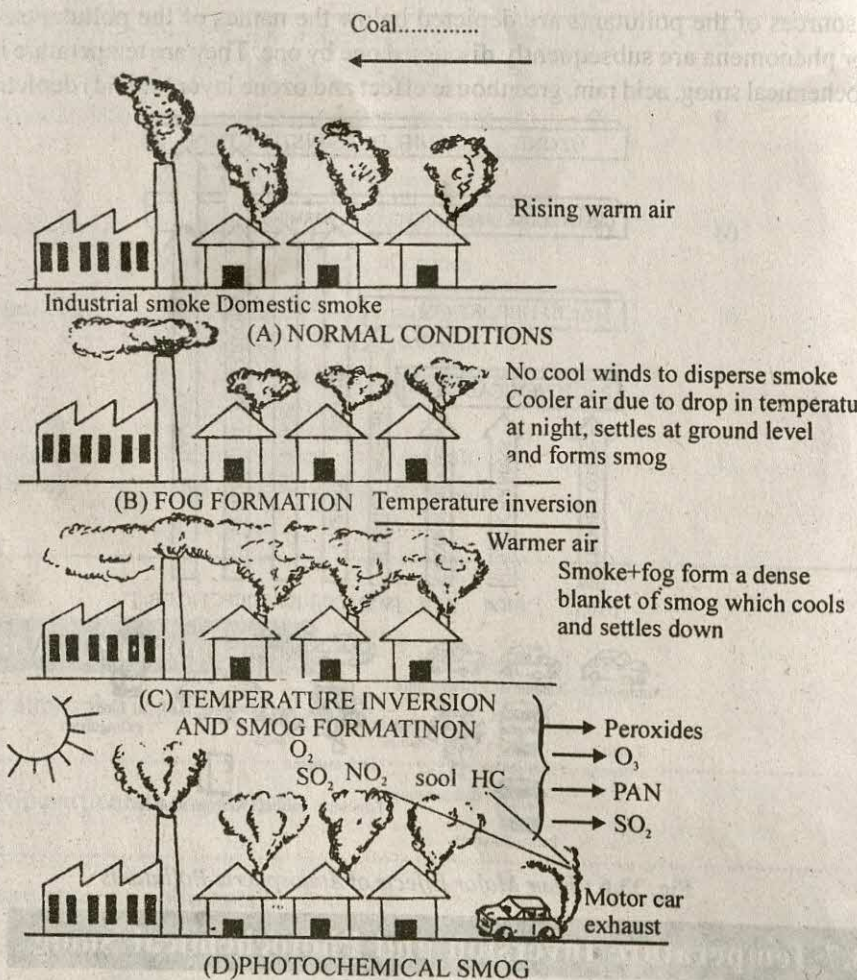
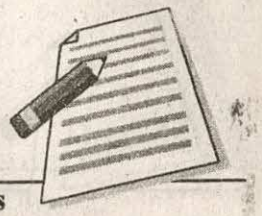


Fig. 33.7 : *Formation of Photochemical Smog and Temperature Inversion*

Exposure to smog causes respiratory problems, bronchitis, sore throat, cold, headache and irritation to eyes (red shot eyes). Smog also damages crops and reduces crop yield.

33.8 Acid Rain

Coal and oil burned by power plants and other industries release SO_2 into air because coal and oil contain small amount of sulphur. Automobile exhausts add SO_2 and nitrogen oxides to the air. Both SO_2 and nitrogen oxides are converted into acids HNO_3 and H_2SO_4 when they combine with oxygen and water vapour in the atmosphere as per the following photo chemical reactions.



$$2SO_2 + O_2 + 2H_2O \rightarrow 2H_2SO_4$$

$$4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$$

This reaction is promoted by O_3 in smog. The acids, so formed are washed down from air to earth during rain or snow fall. It is called acid rain or acid snow. The acids react with minerals present in soil to form sulphates and nitrates due to acid rain.

Rain water even in its purest form is slighlty acidic with pH 5.6 due to dissolved CO_2. But areas near coal and oil burning industries and where motor vehicles ply in large numbers, pH goes down to 2 and rain becomes strongly acidic. Mountain foot hills are the worst affected. There is moisture laden air rises to higher altitudes it condenses to fall as rain or snow, dropping its load of pollutants. In spring. snow melts and adds pollutants to lakes and other water bodies.

When the dissolved pollutants drop as rain or snow (wet deposition) it is termed acid precipitation. Deposition of dry gases and salts is dry deposition. Acid rain spreads over areas of several hundreds to several thousand kilometers.

33.8.1 Effects of Acid Rain

Some of the effects of acid rain are listed below:

(1) Excessive acid concentrations are phytotoxic (toxic to plants). There have been widespread death of trees in forests due to acid rain.

(2) Sea waters are rich in minerals and have great buffering capacity. But buffering capacity of fresh water bodies is low and acid deposits have a toxic effect on the fresh water ecosystems.

(3) Mature (capable of reproduction) fish survives in acid rain fed water bodies but fails to reproduce. So there are no young fish in such waters.

(4) Exposed surfaces of buildings, statues get corroded. Limestone or marble ($CaCO_3$) structures are specially damaged (Fig. 32.8).

The chemical reaction is like

$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$.

The sulphates are leached out by rain water.

(5) Acidic sulphate when present in the atmosphere causes laziness. Acidic mist falling on the ground reduces visibility.

Fig. 33.8 : *A Stone statue showing corrosive effects of Acid Rain*

33.9 Green House Effect and Global Warming

The literal meaning and function of green house is to trap the heat. You must have seen delicate plants being grown in a glass chamber which is comparatively warmer inside than outside. Glass permits solar radiations to come in but restricts the outward movement of heat. The radiations get trapped inside the glass chamber and raises the temperature.

Gases such as CO_2, NO_2, CFCs (chloro fluorocarbons) allow sun rays to pass through them but then absorb and reradiate the heat back towards the earth. These are therefore termed as **green house gases**.

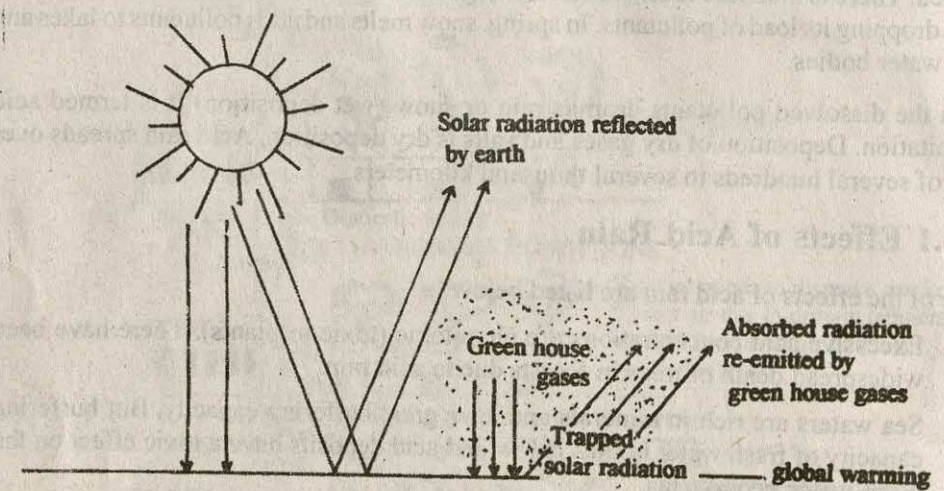


Fig. 33.9 : *Green House Effect*

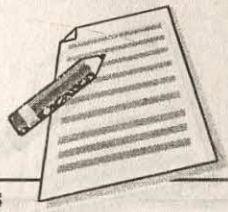
33.9.1 Greenhouse Gases

The common green house gases and their sources of pollution are listed below:

(1)	CO_2	-	from fossil fuel burning.
(2)	NO_2	-	from fertilizer plants, automobile exhaust use and animal waste.
(3)	CH_4	-	from bacterial decomposition, biogas, flooded rice fields.
(4)	CFCs	-	from freon, (a refrigerant), areosol sprays.
(5)	HALONS (halocarbons)	-	from fire extinguishers.

33.9.2 How Does Earth's Atmosphere Trap Heat?

Radiations (ultra violet) from the sun penetrate the earth's atmosphere and reach earth. The surface of earth partially absorbs the radiations. The rest is re-radiated as infrared radiation from the earth's surface. In polluted air, molecules of CO_2, CH_4, CFCs, N_2O, O_3 and water vapours are present. These gases can absorb infrared radiations but cannot absorb the ultra violet radiations. Energy of these trapped radiations raise the temperature of earth and its atmosphere. Thus if proportion of green house gases increases in the atmosphere heat trapped by them will raise the temperature of the earth and will cause global warming.



Notes

Greenhouse effect leading to global warming shall have severe effects on rainfall, sea level, plant and animal growth..

Global warming is defined as the increase in the average global temperature of the atmosphere near earth's surface.

(1) **Rise in sea level:** It is estimated that by the turn of the century a rise of 5°C in global temperature will be due to effect of greenhouse gases if not checked now. Polar ice caps would melt because of rise in temperature and add more water to sea. Moreover water expands when it heats up. This will lead to rise of sea level. It will flood the low lying coastal area and many cities will get submerged in water.

(2) **Drought:** A 3° C warming will result in 10% decrease in precipitation (rain fall) and this will decrease rain fall causing drought conditions.

(3) **Effect on plant growth:** Drought will reduce photosynthesis in plants and lead to reduced growth of plants.

(4) **Effect on animals:** Warmer conditions will encourage growth of pests.

(5) **Water shortage:** Increase in temperature will lead to increased evaporation leading to shortage of water for agricultural, municipal and industrial use.

(6) **Climatic changes :** It has great effect on climate changes. For example, spring now occurs about a week earlier than normal time.

(7) **Increase in CO_2** Warmer conditions accelerate microbial degradation of organic matter and add more CO_2

(8) **Day and Night temperature :** Night temperatures have increased more than day temperature as green house gases prevent heat from escaping at night.

(9) **Formation of ozone hole :**

The atmosphere has two layers, the stratosphere and troposphere. Stratosphere lies 15 km to 50 km above the surface of earth. The energy of the sun splits some molecular O_2 in this layer to give individual (O) atoms which combine with intact molecular oxygen to give O_3. The layer of O_3 forms a shield as it absorbs UV rays and prevent them from striking the earth. If UV rays penetrate our atmosphere the life would not be possible as organisms cannot tolerate heavy doses of UV radiation. Troposphere is the atmospheric layer closest to the earth's surface whose compostion you have already studied. Chloro fluorocarbons and halons released into the atmosphere have destroyed the ozone shield and an **ozone hole** has been detected at the South Pole of Antartic and North Pole of Arctic.

33.10 Depletion of ozone layer

Ozone shield depletion is primarily caused due to the following reasons:

(a) Chlorofluorocarbons (CFCs) are the heat transfer agents used in refrigerators and air conditioners, and foaming agents in foam cups and cartons.

(b) Halons or halocarbons are anti fire agents used in fire extinguishers.

The ozone in the stratosphere is being depleted by the presence of mainly chlorofluorocarbons (CFCs) and halogen gas, particularly chlorine. The highly energetic ultra violet radiation splits up the CFCs, releasing chlorine. The released chlorine is responsible for convertion

of the ozone into oxygen molecule consequently depletion of ozone layer occurs as per the following equations.

$$Cl + O_3 \rightarrow ClO + O_2$$

$$ClO + O \rightarrow Cl + O_2$$

It is believed that one molecule of CFC is capable of destroying 1,00,000 ozone molecules in the stratosphere. The area where the ozone is completely destroyed is known as **ozone hole.** The first ozone hole was observed over Antaractic Ocean.

The important function of ozone layer in the stratosphere in to protect us from dangerous ultra violet (UV) radiations from the sun by absorbing it.

33.10.1 Effects of Ozone Depletion

Ozone layer depletion will allow more UV rays to enter the troposphere and will cause a series of harmful effects such as :

(1) Plants and animals living on the surface will start dying.

(2) UV radiation will fasten the formation of smog

(3) Temperature of the earth will increase leading to rise in sea level and flooding of low lying areas.

(4) More UV rays will directly fall on the skin of humans causing skin cancer.

(5) Leaves of plants will show chlorosis (loss of chlorophyll and yellowing),

33.11 Effects of Air Pollution on Humans

Air is mobile and impact of air pollution on ecosystems is reduced as wind blows away pollutants. But when winds are calm, air pollution becomes not only damaging but life threatening.

The damaging effects of atmospheric pollution have been described along with the account on pollutants. Long term exposure to moderate pollution causes more discase and death. Some adverse effects of air pollution on humans are summarised in table 33.3.

Table 33.3 : Effects of air pollutants on humans

Disease / Discomfort	Caused by
Emphysema. Bronchitis	CO, SO_2, PAN, O_3
Eye irritation, headache	SO_2, PAN, O_3
Silicosis. Asbestosis	Suspended particulate matter like silica, asbestos.
Coronary artery disease	Tobacco smoke
Anemia, kidney, liver damage	Pb
Fluorosis, Skin Cancer	Fluorides
Poisoning death	CO

33.12 Control of Air Pollution

The alarming rate at which the atmosphere is being polluted, soon there will be more ailing human beings than healthy. The need of the hour is to put a quick check to atmospheric pollution.

Since most of air pollutants are emitted during combustion of fossil fuels, there are two practical approaches for air pollution control which are discussed below :

(i) One approach is control undesirable changes in the air we breathe by observing the following precaution :

(a) Limiting pollutants into air by using sulphur-free oil and coal, using catalytic convertors in automobiles and avoiding burning of waste material.

(b) Taking stringent measures against release of emissions from industries.

(ii) The other approach is to use sources of energy other than fossil fuels such as wind, water, solar power, etc. Use bicycles and battery powered cars rather than vehicles with internal combustion engines. Service vehicles should use lead free petrol.

Above all, it is necessary to educate the general public. Air pollution should become every human being's concern. Only then will the air become more congenial to healthy living.

Intext Questions 33.3

1. What is smog?

   .....

2. Name two photochemical oxidants.

   .....

3. Name two gases which form acid rain.

   .....

4. Mention any four greenhouse gases.

   .....

5. What are the sources of freons and halons in air?

   .....

6. What effect does acid rain have on marble statues ?

   .....

7. Mention one measure to control air pollution.

   .....

What You Have Learnt

- Nature's balance has beeen upset by human activities releated to urbanisation, industrialisation and intensive agriculture.
- Atmosphere is made up of gases of which nitrogen - 78%, oxygen - 21%, carbondioxide - 0.1 to 0.3%, inert gases 1 %
- Increase of temperature with altitude is known as positive lapse rate where as decrease in temperature with increase of altitude is negative lapse rate of temperature.
- Carbon is actively cycled between its inorganic form to organic form through respiratioin and photothenthesis. Decay cycle converts organic carbon to inorganic carbon.
- During respiration food is oxidised through a series of enzyme controlled steps in which chemical bonds of glucose are broken down to release energy and CO_2 is liberated.

- In photosynthesis green plants trap solar energy and synthesize starch from CO_2 and H_2O. Oxygen is released into air.
- After death of organisms are degraded by microorganisms. The carbon in organisms moves back enviornoment.
- Air pollution is due to

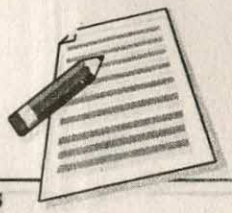
  (i) particulate matter (soot, dust)

  (ii) aerosols composed of hydrocarbons

  (iii) gases like SO_2, NO_2 are mostly released by burning fossil fuels.
- NO_2 and hydrocarbons are modified by sunlight to form photochemical smog. Smog is a combination of smoke and fog. Automobile exhausts give out NO_2 and hydrocarbons. They form PAN (peroxyacetyl nitrate) which along with ozone and SO_2 forms photochemical smog.
- Smog cools and settles down near the earth and forms a blanket, while warmer air covers it. Thus there is a 'temperature inversion' with warm air above and cool air below unlike in the normal conditions.
- SO_2 and NO_2 form acids which drop as H_2SO_4 and HNO_3 on statues and spoil them. This is called acid precipitation. Acid rain kills trees, prevents reproduction in fish and causes poor visibility.
- Greenhouse gases are CO_2, NO_2, CH_4, chlorofluorocarbons and halons. They trap solar radiation and cause global warming.
- Global warming due to greenhouse effect leads to drought, rise in sea level, lack of rain and water shortage.
- There is a layer of ozone in stratosphere, which protects us from UV radiation by absorbing it.
- Chlorofluorocarbons which are used in refrigerators and foam cups as aerosols and halons used in fire extinguishers, when released into the air cause depletion of ozone shield which protects us from harmful effects of solar radiations. It is feared that ozone depletion will have damaging effects on humans such as causing skin cancer.
- Complete destruction of ozone layer over an area is termed as ozone hole.
- Air pollution causes respiratory diseases such as emphysema and bronchitis, eye irritation, fluoroisis, cancer and may even be fatal.
- Control measures include use of sulphur free oil and coal, use of alternative sources of energy such as wind and solar power, use bicycle and battery powered vehicles, stop burining waste indiscriminately, have stringent measures for release of emissions from industries and above all educate general public and caution them against releasing air pollutants.

Terminal Exercise

1. How are fossil fuels formed in nature?
2. What are the damaging effects of SO_2 and NO_2 on plants and animals?



3. Write a note on carbon monoxide poisoning.
4. What is thermal inversion and how is it caused?
5. Enumerate the various effects of acid rain.
6. What is ozone hole? What are the effects of ozone depletion?
7. Why does sea level rise due to global warming?
8. How do greenhouse gases cause global warming.
9. Mention five disease/discomforts in humans caused by different air pollutants.
10. Enumerate the various measures of control of air pollution.

Answers to Intext Questions

33.1

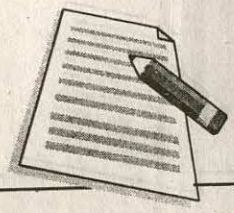
1. nitrogen
2. nitrogen and oxygen
3. plants; because they synthesize their own food
4. glucose
5. chlorophyll
6. through decay and decomposition
7. consumers
8. (i) volcanic eruption and (ii) combustion
9. Stratosphere

33.2

1. undesirable level of undesirable and harmful substances in the atmosphere
2. soot, fluoride, Pb dust, NaCl (any two)
3. SO_2, CO_2, CO, NH_3, H_2S (any two)
4. methanogenic bacteria, ruminant stomach, fermentation in water logged paddy fields (any one).
5. PAN and O_3

33.3

1. fog and smoke
2. O_3 and PAN
3. SO_2 and NO
4. CO_2, NO_2, CH_4, CFC, Halons
5. refrigerants, fire extinguishers
6. corrode them
7. reducing use of fuel which releases air pollutants and use clean renewable fuels. Educate everyone about dangers of pollution.



Notes

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WATER POLLUTION

Water is essential for the existence of all life forms. In addition to household uses, water is vital for agriculture, industry, fishery and tourism etc. Increasing population, urbanisation and industrialisation has led to the decreased availability of water. The quality of water used is also being deteriorated as it is getting more and more polluted. You may be aware of at least some health hazards and harmful effects of water pollution. In this lesson a detailed account of various types, sources and effects of water pollutants is given. Some methods of water pollution control and legislatures involved have also been discussed.

Objectives

After reading this lesson, you will be able to:

- list earth's water resources;
- define water pollution and its different parameters;
- list the major types of water pollutants, their sources and effects;
- distinguish between natural and man -made pollutants;
- use the concept of biological oxygen demand (BOD) and account for the changes in a water body;
- state methods for the prevention of water pollution;
- compare primary, secondary a... tertiary treatment of sewage and
- know necessary legislative measures for prevention of water pollution in the country.

34.1 Water Resources on Earth

You may be aware that about three fourths of our planet earth's surface is covered by water. However, very little of it is available for consumption. Most (about 97%) of the water on earth is present in the seas and oceans. It is too salty to be of any use for

drinking, agriculture and industrial purposes. The remaining 3% is fresh water; 75% of which is locked up in the polar ice caps and in glaciers and quite deep under the earth's surface as underground water. The fresh water, which we can use, comes to us from two sources:

i) Surface water

ii) Ground water

Let us learn about these in detail.

(i) Surface Water: Rain and snow are good natural resources of fresh water. It is estimated that of all the precipitation (rain water and snow) that falls on the earth, about one-third is absorbed by the plants and another one-third seeps down into the soil and the remaining one third runs off the surface into streams and rivers. This part of precipitation, which runs off to form streams, rivers and lakes, is called the **surface** water.

Precipitation (rain or snow) that runs-off into stream, rivers and lakes is called surface water.

The small fraction of usable surface water is continuously replenished by means of the hydrological cycle, Fig 33.1.

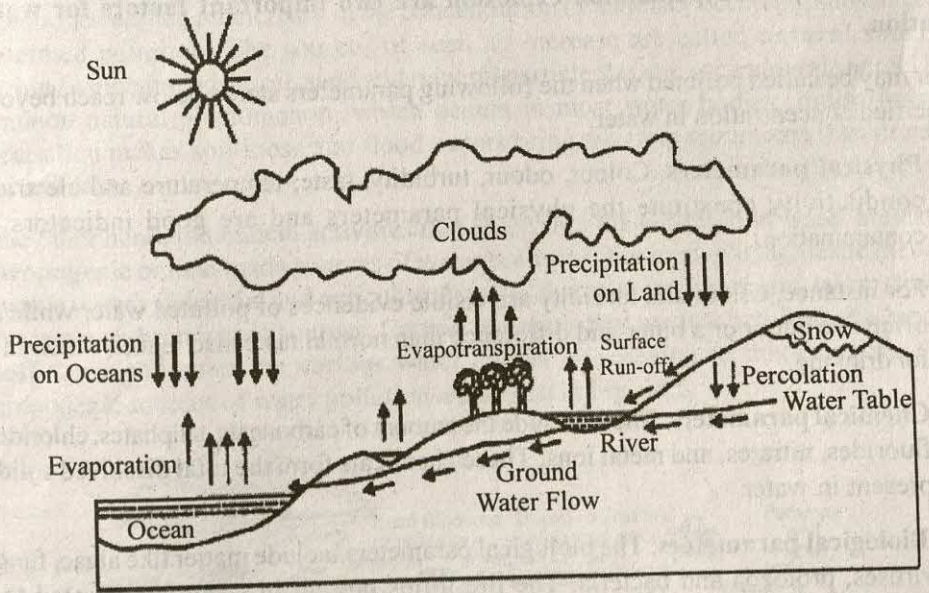


Fig. 34.1: *A schematical representation of Hydrological cycle*

The hydrological cycle involves evaporation of water from oceans, rivers and other sources to form clouds. The clouds on saturation with water vapours cause precipitation falling back on earth's surface. On surface, the water runs off to rivers and finally to oceans. The water again evaporates and the cycle continues.

Surface water has a natural tendency to clean itself as it contains certain organisms that break down pollutants into harmless substances.

(ii) Ground Water: The part of precipitation that seeps into the ground as a result of gravity and fills the pores between soil particles and rocks under it is called **ground**

water. The water bearing layers of soil and rocks are called **aquifers**. Ground water is very important for agricultural and industrial purposes. Ground water in the form of wells and springs is often the only source of water supply especially in villages and small towns.

In spite of a good number of water resources, we have shortage of usable water. This is due to increasing population, urbanisation and industrialisation. There is a need to optimise use of water and also conserve surface run off of water by means of rainwater harvesting, groundwater conservation, making use of recycling methods etc.

34.2 Water Pollution – Parameters

A large amount of water is discharged back after domestic and industrial usage. This is contaminated with domestic waste and industrial effluents. When this contamination reaches beyond certain allowed concentrations, it is called **pollution** and the contaminants are called the **pollutants**. **Water pollution** may be defined as the contamination of streams, lakes, seas, underground water or oceans by substances, which are harmful for living beings. If the concentration of substances naturally present in water increases then also the water is said to be polluted.

Water pollution may be defined as the contamination of streams, lakes, seas, underground water or oceans by substances, which are harmful for living beings. Industrialisation and population explosion are two important factors for water pollution.

Water may be called polluted when the following parameters stated below reach beyond a specified concentration in water.

i) **Physical parameters**. Colour, odour, turbidity, taste, temperature and electrical conductivity constitute the physical parameters and are good indicators of contamination.

   For instance, colour and turbidity are visible evidences of polluted water while an offensive odour or a bitter and difference than normal taste also makes water unfit for drinking.

ii) **Chemical parameters**: These include the amount of carbonates, sulphates, chlorides, fluorides, nitrates, and metal ions. These chemicals form the total dissolved solids, present in water.

iii) **Biological parameters**: The biological parameters include matter like algae, fungi, viruses, protozoa and bacteria. The life forms present in water are affected to a good extent by the presence of pollutants. The pollutants in water may cause a reduction in the population of both lower and higher plant and animal lives. Thus, the biological parameters give an indirect indication of the amount of pollution in water.

34.3 Water Pollution – Sources

Water pollutants refer to the substances which are capable of making any physical, chemical or biological change in the water body. These have undesirable effect on living organisms. As mentioned earlier, the water used for domestic, agricultural and industrial purposes is discharged with some undesirable impurities in it. This contamination leads to the pollution

of water, which is generally called the **fresh water pollution**. Fresh water pollution may be classified into two types: **surface water pollution** and **ground water pollution**.

34.3.1 Surface Water Pollution

When pollutants enter a stream, river or lake these gives rise to surface water pollution. The surface water pollution has a number of sources. These can categorised as:

- Point and Non-point Sources
- Natural and Anthropogenic Sources

(i) Point and Non-point Sources

The well-defined sources that emits pollutants or effluents directly into different water bodies of fresh water are called **point sources**. Domestic and industrial waste are examples of this type. The point sources of pollution can be effectively checked. On the other hand, the **non-point sources** of water pollution are scattered or spread over large areas. This type of sources deliver pollutants indirectly through environmental changes and account for majority of the contaminants in streams and lakes. For example, the contaminated water that runs off from agriculture farms, construction sites, abandoned mines, enters streams and lakes. It is quite difficult to control non-point sources.

(ii) Natural and Anthropogenic Sources

As mentioned earlier, an increase in the concentration of naturally occurring substances is also termed pollution. The sources of such an increase are called **natural sources**. **Siltation** (which includes soil, sand and mineral particles) is one such natural source. It is a common natural phenomenon, which occurs in most water bodies. Indiscriminate deforestation makes soil loose and flood waters bring silt from mountains into streams, rivers and lakes.

On the other hand, the human activities that result into the pollution of water are called **anthropogenic** or man made sources of water pollution. For example, domestic (sewage and waste water), industrial and agricultural wastes that goes into the rivers, lakes, streams and seas are anthropogenic sources. Certain materials that are leached from the land by run-off water and enter the various water bodies also belong to this category. The anthropogenic sources of water pollution are shown in Fig. 34.2.

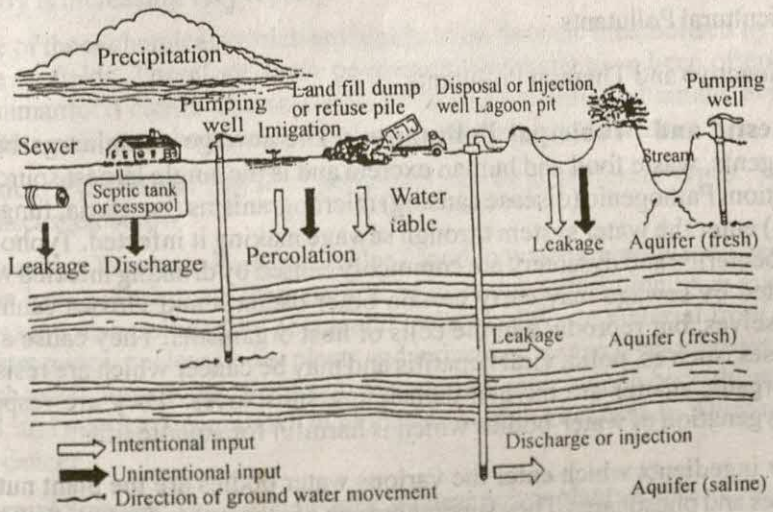


Fig. 34.2 : *Anthropogenic Sources of water pollution*

34.3.2 Ground Water Pollution

When the polluted water seeps into the ground and enters an aquifer it results into **ground water pollution**. The most of our villages and many townships, ground water is the only source of drinking water. Therefore, pollution of groundwater is a matter of serious concern. Groundwater gets polluted in a number of ways. The dumping of raw sewage on soil, seepage pits and septic tanks cause pollution of groundwater. Fig. 34.3. The porous layers of soil hold back solid particles while the liquid is allowed to pass through. The soluble pollutants are able to mix with the groundwater. In addition to these, the excessive use of nitrogenous fertilizers and unchecked release of toxic wastes and even carcionogenic substances by industrial units many ressult in slow trickling down through the earth's surface and mixing with the groundwater. This problem is very serious especially in areas where water table is high (i.e., where water is available near surface of earth).

The ground water can move over large distances by virtue of the large empty space available below the earth's surface. This way if some impurities seep into the ground water at one point, they may be observed at a different point far removed from the point of source. In such a case it is difficult to estimate the source of water pollution. However, suspended impurities and bacterial contaminants are removed in the process of seepage by the soil acting as an absorbent and filter, and water acting as a solvent.

Since the movement of groundwater through the porous rock is very slow, pollutants which get mixed with the groundwater are not readily diluted. Furthermore, groundwater does not have access to air (in contrast to surface water) therefore, oxidation of pollutants into harmless products in groundwater does not occur.

34.4 Water Pollutants

You have read the various sources from where pollutants enter the water bodies. Let us now learn about the various types of pollutants arising out of these sources. These can be broadly put under the following types.

(i) Sewage Pollutants (Domestic and Municipal Waste)

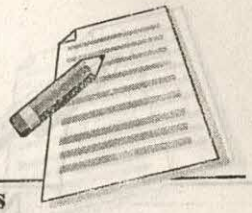
(ii) Industrial Pollutants

(iii) Agricultural Pollutants

(iv) Radioactive and Thermal Pollutants

(i) Domestic and Municipal Pollutants : The sewage contains garbage, soaps, detergents, waste food and human excreta and is the single largest sources of water pollution. Pathogenic (disease causing) microogranisms (baccteria, fungi, protozoa, algae) enter the water system through sewage making it infected. Typhoid, chloera, gastroenteritis and dysentery are commonly caused by drinking infected water. Water polluted by sewage may carry certain other bacteria and viruses cannot grow by themselves, but reproduce in the cells of host organisms. They cause a number of diseases, such as, polio, viral hepatitis and may be cancer which are resistant to like the organic matter are oxygen demanding substances. They are responsible for deoxygenation of water-bodies which is harmful for aquatic life.

Other ingedients which enter the various water bodies are the plant nutrients, i.e., nitrates and phosphates. They support growth of algae, commonly called **algal bloom** (blue-green species). This process is called **eutrophication** and is discussed in



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details in the next section.

(ii) **Industrial Pollutants :** Many industries are located near rivers or fresh water streams. These are responsible for discharging their untreated effluents into rivers like highly toxic heavy metals such as chromium, arsenic, lead, mercury, etc. along with hazardous organic and inorganic wastes (e.g., acids, alkalies, cyanides, chlorides, etc.). River Ganges recives wastes from textile, sugar, paper and pulp mills, tanneries, rubber and pesticide industries. Most of these pollutants are resistant to breakdown by microorganisms (called nonbiodegradable), therefore damage the growth of crops and the polluted water is unsafe for drinking purposes.

Factories manufacturing plastic, caustic soda and some fungicides and pesticides release mercury (a heavy metal) along with other effluents in nearby water body. Mercury enters the food chain through bacteria, algae, fish and finally into the human body. The toxicity of mercury became evident by the Minamata Bay tragedy in Japan during the period 1953-60. Fish died due to mercury consumption and those who ate fish were affected by mercury poisoning and quite a few died. The milder symptoms of mercury poisoning are depression and irritability but acute toxic effects can cause paralysis, blindness, insanity, birth defects and even death. The high concentration of mercury in water and in fish tissues results from formation of soluble monomethylmercury ion, (CH_3, Hg^+) and volatile dimethylmercuty [$(CH_3)_2$ Hg] by anaerobic bacteria in sediments.

(iii) **Agricultural Waste:** Manure, fertilizers, pesticides, wastes form farms, slaughterhouse, poultry farms, salts and silt are drained as run-off from agricultural lands. The water body receiving large quantities of fertilizers (phosphates and nitrates or manures becomes rich in nutrients which leads to eutrophication and consequent depletion of dissolved oxygen. Consumption of water rich in nitrates is bad for human health especially for small children.

Pesticides (DDT, dieldrin, aldrin, malathion, carbaryl etc.) are used to kill insect and rodent pests. Toxic pesticide residues enter the human body through drinking water or through food chain (biomagnification). These compounds have low solubility in water but are highly soluble in fats. For example, the concentration of DDT in river water may be very low but some fish over a period of time accumulate so much of DDT that they become unfit for human consumption. The use of pesticides in our country is increasing very rapidly.

Some of these chemicals which are highly toxic become metabolised by animals that graze on fields. Therefore, these poisonous chemicals have been often observed in the humanfood chain. The presence of these chemicals in humans even in minute amounts can cause hormonal imbalance and may lead to cancer.

(iv) **Physical Pollutants:** Physical pollutants can be of different types. Some of them are discussed below :

(a) **Radioactive Wastes** : Radionucleides found in water are radium and potassium-40. These isotopes originate from natural sources due to leaching from minerals. Water bodies are also polluted by accidental leakage of waste material from uranium and thorium mines, nuclear power plants and industries, research laboratories and hospitals which use radioisotopes. Radioactive materials enter human body through water and food, and may be accumulated in blood and certain vital organs. They cause tumours and cancer.

(b) **Thermal Sources**: Various industries, nuclear power plants and thermal plants require water for cooling and the resultant hot water is often discharged into rivers or lakes.

This results in thermal pollution and leads to the imbalance in the ecology of the water body. Higher temperature lowers the dissolved oxygen level (which is very essential for marine life) by decreasing the solubility of oxygen in water. Fish and other aquatic organism can get affected by a sudden change in water temperatures.

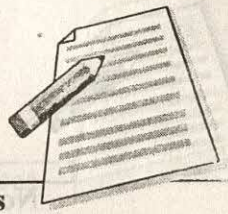
(c) **Sediments** : Soil particles carried to streams, lakes or oceans form the sediments. The sediment become polluting due to their large amount. Soil erosion defined as the soil carried by flood water from crop land, is responsible for sedimentation. The sediments may damage the water body by introducing a large amount of nutrient matter.

(v) **Petroleum Products:** Petroleum products are widely used for fuel, lubrication, plastics manufacturing, etc. and happen to be poisonous in nature. Crude oil and other related products generally get into water by accidental spillage from ships, tankers, pipelines etc. Besides these accidental spills, oil refineries, oil exploration sites and automobile service centres pollute different water bodies. Oil slick which floats on the water surface causes death of marine life and severely affects the ecosystem of the ocean.

A list of various types of water pollutants, their sources and effects have been summarised in Table 34.1.

Table 34.1: Types of water pollutants, their sources and effects

	Pollutant	Sources of Pollutants	Effects and Significance
1	Pathogens	Sewage, human and animal wastes, natural and urban runoff from land, industrial waste	Depletion of dissolved oxygen in water (foul odour) health effects (outbreaks of water borne diseases)
2	Organic pollutants • Oil and grease • Pesticides and weedicides • Plastics • Detergents	Automobile and machine waste, tanker spills, offshore oil leakage Chemicals used for better yield from agriculture Industrial and household waste Industrial and household waste	Disruption of marine life, aesthetic damage Toxic effects (harmful for aquatic life), possible genetic defects and cancer; kills fish Eutrophication, aesthetics
3	Inorganic pollutants Fertilizers (phosphates and nitrates)	Agricultural runoff	Algal bloom and eutrophication, nitrates cause methemoglobenemia
	Acids and alkalies	Mine drainage, industrial wastes, natural and urban runoff	Kill fresh water organisms, unfit for drinking, irrigation and industrial use.
4	Radioactive materials	Natural sources, uranium mining and processing, hospitals and research laboratories using radioisotopes	Cancer and genetic defects
5	Heat	Cooling water for industrial, nuclear and thermal plants	Decreases solubility of oxygen in water, disrupts aquatic ecosystems
6	Sediments	Natural erosion, runoff from agricultural land and construction sites	Affects water quality, reduces fish population



Intext Questions 34.1

1. Define water pollution.

   .....

2. What do you understand by surface water?

   .....

3. List any three anthropogenic sources of water pollution?

   .....

4. List the parameters indicating water pollution.

   .....

5. Name the element which causes Minamata disease?

   .....

34.5 Water Pollution and Some Biological Effects

The natural source of water in the form of precipitation or rain is the purest form available in nature. However after reaching the surface and then underground it gets contaminated by a number of pollutants. There are some biological factors also mentioned earlier responsible for spoiling the quality of water. These include the lower plants like algae and bacteria which are the causes of nutrient accumulation in aquatic systems. This nutrient accumulation gives rise to a condition called eutrophication explained below.

34.5.1 Eutrophication

Eutrophication is a process by which a water body slowly becomes rich in plant nutrients such as nitrates and phosphates due to soil erosion and run off from the surrounding land. Let us try to understand this phenomenon. A water system like a lake or any reservoir may get a large inflow of organic matter from domestic wastes and run off from the surrounding land. Increasing human population, intensive agriculture and rapid industrial growth have led to an increasing release of domestic waste, agricultural residues, industrial wastes and land run-off into various water bodies. Nutrients are released from organic waste by aerobic (oxygen requiring) bacteria which start decomposing it. Dissolved oxygen is consumed in this process. As more and more organic matter enters a water body, more is the deoxygenation of the water body and larger is the production of nutrients. These nutrients fertilize an abnormal growth of algae and other large water plants such as duckweed. As more plants grow, some of them die also due to larger oxygen demand and therefore oxygen deficiency in the water body (i.e., deoxygenation of the water body). Such a water body is said to be **eutrophied** and the process is called **eutrophication**. The word eutrophication is derived from the Greek word which means well nourished as (eu:true, trophos:feeding)

Eutrophication of a water body results due to the release of large amount of nutrients by the action of aerobic bacteria on organic wastes entering a water body naturally or by human activity.

The above discussion leads us to a concept called biological oxygen demand (BOD). Let us try to understand by the description given below.

34.5.2 Biological Oxygen Demand (BOD)

The quality of oxygen used up by microorganisms at 27°C and in darkness during 3 days in breaking down organic wastes in a water body is called its **biological oxygen demand (BOD).**

It can be explained in the following manner.

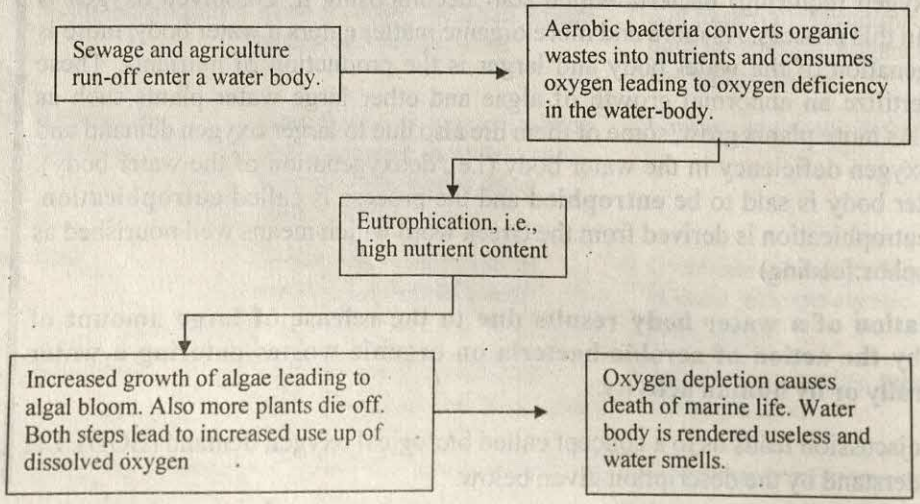
You know that there are many organic compounds or waste present in a water body. The microorganisms present in the system act upon this waste for their own consumption and growth. In the process the metabolic activity requires oxygen which is met by the dissolved oxygen present in water. It is this amount of oxygen which is defined as **biological oxygen demand (BOD).** The BOD value of an aquatic system depends upon:

- the type and amount of organic waste
- the organisms acting on it
- temperature and pH

The greater the amount of organic waste in the water body, the greater is the amount of oxygen required to break it down biologically and therefore higher is the BOD value of water. This value is a good measure in evaluating the degree of pollution in a water body. The less polluted water shows comparatively low value of BOD. Its value is used as a criterion for managing water pollution of a water body. An evaluation is made by determining oxygen concentration in water before and after incubation at 20°C in dark for 5 days.

34.5.3 Biomagnification

A variety of toxic chemicals move through food chains. Toxic pesticides may be sprayed for controlling insect pests, fungi, herbs, but they concentrate in the food chain and harm to other (non target) organisms. For example, DDT was sprayed in the U.S. to control mosquitoes at a concentration expected to be harmless to non target organisms like fish and birds. DDT accumulated in the marshes and planktons. Planktons were eaten by fish and the fish had a higher concentration of DDT in its body. Further, when birds ate the fish, they accumulated still higher concentration. This increase in concentration of accumulated toxic chemicals as one goes higher in the food chain is termed **biomagnification.** Biomagnification has at times threatened the reproduction and survival of carnivores (secondary consumers) who occupy the highest level of the food chain.



34.6 Water Pollution – Some Control Measures

Waste water generated by household activity, industries or garbage landfills is called **sewage** which is classified as the municipal water pollution. Sewage contains solid matters in the form of suspended colloidal and dissolved organic matter, detergent, mineral matter, nutrients and gases. Sewage is one of the major causes of water borne diseases and therefore the treatment of sewage is one of the important tasks. For a long time treatment of municipal waste in the form of sewage involved mainly of the removal of suspended solids, oxygen demanding materials and harmful bacteria. Now the disposal of the solid residue from sewage has been improved by applying municipal treatment processes.

The treatment of this waste water is carried out in the following three stages:

(i) Primary treatment

(ii) Secondary treatment, and

(iii) Tertiary treatment

Primary Treatment: When the waste water is to be dumped off into a river or flowing steam, the treatment is carried out by sedimentation, coagulation and filtration. This is known as primary treatment. If the water is required for drinking purposes, it has to undergo further treatment called secondary and tertiary treatments. The following steps are performed to do primary treatment of water:

(i) **Sedimentation**: This step is carried out in large tanks specially built for this purpose in sewage treatment plant. The polluted water is allowed to settle so that silt, clay and other matter settle to be bottom and water is slowly allowed to move out. Fine particles do not settle and are thus required to be removed in the next step.

(ii) **Coagulation**: Fine particles and colloidal suspension are combined into large particles by a process called coagulation. This step is carried out by the addition of special chemicals called coagulants (flocculants) such as potash alum. The large particles either settle to the bottom or are moved in the next step.

(iii) **Filtration**: Suspended particles, flocculants, bacteria and other organisms are filtered by passing the water through a bed of sand or finely divided coal or through some fibrous materials. The total impurities collected in these steps are called **sludge**. It is used as a valuable fertilizer. On composting (i.e. the action of anaerobic bacteria), it releases sludge gas. It consists mainly of methane gas which is used for cooking purposes.

Secondary or Biological Treatment: The water after primary treatment is not fit for drinking purposes and has to undergo further treatment. This is done through secondary or biological treatment. A commonly used method is to allow polluted water to spread over a large bed of stones and gravel so that the growth of different microorganisms needing nutrients and oxygen is encouraged. Over a period of time a fast moving food chain is set up. For example, bacteria consume organic matter from the polluted water; protozoa live on bacteria. Every form of life including algae and fungi help in the cleaning up process. This is called secondary treatment of water. It involves the following processes

(i) **Softening** : By this treatment undesirable cations of calcium and magnesium are removed from hard waters. Either water is treated with lime and soda ash to precipitate Ca^{2+} ions as carbonates or it is passed through cation exchangers. This makes water soft.

(ii) **Aeration**: In this process, soft water is exposed to air by forcing air through it to add oxygen to water. This encourages bacterial decomposition of organic matter into harmless products such as carbon dioxide and water. The addition of oxygen reduces carbon dioxide. sulphide etc.. The water is as yet not fit for drinking purposes. The pathogenic and other microorganisms need to be killed. This is done in the next treatment.

Tertiary Treatment : The tertiary treatment is actually disinfecting water. Chlorine is the most commonly used disinfectant used for killing bacteria. However, chlorine also reacts with traces of organic matter present in water and forms undesirable chlorinated hydrocarbons (toxic and potentially carcinogenic). It is therefore desirable to reduce the organic matter in water before passing chlorine gas. Other methods of disinfection such as ultraviolet radiation, ozone gas treatment or reverse osmosis are preferred over chlorine treatment. But these methods are more expensive. Fig.34.3 gives a clear picture of the process of sewage treatment in total.

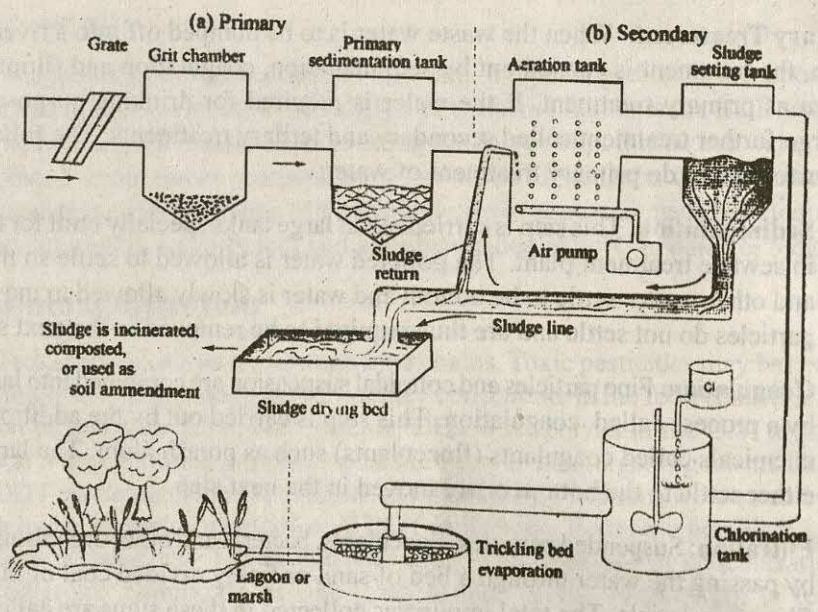


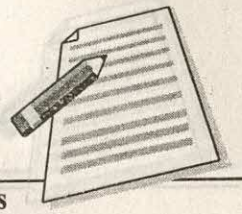
Fig 34.3 : *Treatment process of sewage*

In a treatment plant, the waste is passed through a series of screens, chambers and chemical processes to reduce its bulk and toxicity. During primary treatment a large percentage of suspended solids and inorganic material is removed from sewage. The secondary stage reduces organic material by accelerating natural biological processes. Tertiary treatment is done when water is to be reused. Here 99% of solids are removed and various chemical processes are used to ensure that water is free from infecting materials.

Intext Questions 34.2

1. Define eutrophication.

.....



2. Why does aquatic life get killed in an eutrophied pond?

.....

3. What is the significance of BOD?

.....

4. What is biomagnification?

.....

34.7 Legislative Measures for Preventing Water Pollution

It is important to utilise a good quality and unpolluted water. The quality criteria may vary depending on the use. Individual efforts do pay in this regard, however, a common policy in the form of legislation is always more effective. The enactment of 'Prevention and Control of Water Pollution Act' in 1974 has helped in the prevention of water pollution. The standards have been prescribed for water pollution under Environment (Protection) Act 1986. These are given as follows.

- General standards for water pollutants for discharge of effluents in water bodies on land (inland surface water, public sewers, irrigated land and coastal areas)
- Standards specific for each type of industry
- Standards defined for the amount of waste water to be discharged for different industries
- Standards limiting the amount of a particular pollutant on the basis of production capacity of an industrial unit

The state pollution control boards have also been empowered to grant/renew consent to new/existing water polluting industries under water 'Prevention and Control of Pollution Act-1974.' They have been empowered to shut down any industrial unit which fails to meet the prescribed standards under this Act. The state governments have also been authorized to take punitive measures against defaulting industries.

It becomes imperative to act upon the above mentioned rules and regulations and also follow measures at individual end to improve the quality of water used for various purposes.

Intext Questions 34.3

1. How is sludge utilized?

.....

2. Mention the steps by which polluted water is made fit for drinking purpose?

.....

3. Why is chlorination not the most desirable method of disinfecting polluted water?

.....

What You Have Learnt

- Water pollution refers to any physical, chemical or biological change that has an undesirable affect on living organisms.
- Sewage, industrial, agricultural pollution and physical pollutants are the various sources of water pollution. These sources may be limited to a point sources or spread over large areas (non-point sources).
- Sewage, fertilizers, detergents, toxic wasters released by industries are some of the sources of groundwater pollution.
- Phosphatic, and nitrogenous fertilizers cause algal bloom and severe oxygen depletion in water body. The water body is said to be eutrophied.
- The quantity of oxygen needed by micro-organisms in degrading organic wastes in a water body is defined in terms of its biological oxygen demand (BOD).
- Biological magnification of toxic materials released into water bodies poses a serious threat to aquatic life and eventually to human life.
- Polluted water may be made useful for human consumption by subjecting it to various treatments.
- Legislative measures have been enacted in our country to restrict the pollution of various water bodies.

Terminal Exercise

1. What are the various types of water pollutants? State their consequences.
2. What are the effects of detergents on fresh water bodies?
3. What are the various sources of groundwater pollution?
4. How is the disease 'methaemoglobinaemia' caused?
5. suggest steps to stop eutrophication of water body.
6. What was Minamata Bay tragedy?
7. Which precaution is necessary before purifying the drinking water through chlorination?

Answers to Intext Questions

34.1

1. Nitrate ions are converted by intestinal bacteria into nitrities. These ions combine with haemoglobin to form methaemoglobin thus inhibting the supply of oxygen. This causes & disease known as methaemoglobinaemia.
2. Refer to section 34.4

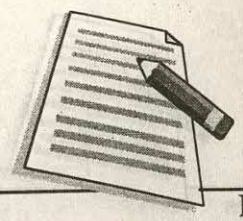
3. Refer to section 34.3.1.
4. Refer to section 34.1
5. Mercury

34.2

1. Refer to section 34.5.1
2. Refer to section 34.5.1
3. Refer to section 34.5.2
4. Refer to section 34.5.3

34.3

1. As fertilizer.
2. Primary treatment including sedimentation, coagulation, filtration Secondary treatment including softening and aeration and Tertiary treatment involving disinfection of water.
3. Because chlorine reacts with organic matter to produce highly toxic chlorinated hydrocarbons which can cause cancer.



Notes

35

HEAVY METAL CONTAMINATION

Many metals occur in traces in the earth's crust. Metals like Pb, Hg, Zn, Cd are heavy metals. Some of the heavy metals are beneficial to organisms in traces. But if excessive levels of heavy metals enter environment through human activities, they endanger health and survival of humans and other organisms. You shall learn about toxic effects of a few heavy metals in this lesson.

Objectives

After reading this lesson, you will be able to

- define heavy metal;
- list the sources of contamination of the environment by heavy metals;
- explain the effects of Pb, Hg, Cd contamination on living organisms and
- list the preventive measures and measures for reduction of heavy metal contamination.

35.1 What is a Heavy Metal?

A heavy metal is one whose density is more than 5g cm^{-3}. Some heavy metals are lead, cadmium, mercury, arsenic selenium, as also iron, copper, manganese, selenium, zinc, etc. All these metals have atomic number greater than 20. Low concentrations of metal like iron, copper, zinc and some others are essential for organisms. They are called 'trace metals'. On the other hand metals like lead, mercury, cadmium and some others are toxic to organisms above a certain concentration.

A trace metal is defined as one which occurs in 1000 ppm (parts per million or mg/litre) or less in the earth's crust.

35.2 Sources of Contamination of Environment by Heavy Metals

Heavy metals are introduced into the environment either by natural means or by human activities.

Natural sources: In nature excessive levels of trace metals may occur by geographical phenomena like volcanic eruptions, weathering of rocks, leaching into rivers, lakes and oceans due to action of water.

Anthropogenic Sources : Small amounts of heavy metals are released while mining and uncontrolled smelting of large quantities of metal, ores in open fires. With the industrial revolution, metals were extracted from natural resources and processed in the industries from where heavy metals passed on into the atmosphere. Similarly traces of heavy metals get into the environment through discharge of waste - both domestic, agricultural and from auto exhausts. Following list shows the various human activities through which heavy metals get into the environment.

(i) Smelting or processing of ores of metals.

(ii) Mining.

(iii) Burning of fossil fuels such as coal, petrol, kerosene oil.

(iv) Discharging agricultural waste.

(v) Discharging industrial waste.

(vi) Discharging domestic waste.

(vii) Discharge from auto exhausts.

(viii) Using pesticides containing compounds (salts) of heavy metals.

35.3 How do Heavy Metals Reach the Ecosystem?

Many toxic inorganic and organic compounds and heavy metals from sources mentioned above, are deposited and buried in the soil by water. They reach the water bodies when washed off from soil by water. Humus, the organic material present in the soil (which also makes the soil look green) has high affinity for heavy metal cations and extract them from water that passes through the soil. Roots of crops and other plants pick up these compounds along with water and pass on to plants and then plants to animals.

Heavy metals are also retained in the soil by adsorption on mineral particles present in the soil and precipitation reactions.

In water, particles with adsorbed heavy metals settle to the bottom and then sediments may accumulate over them. But if organisms consume these, then heavy metals enter the food web.

35.4 Heavy Metal Toxicity

Extraction and trading of metals have been in practice since early days. Heavy metals like iron, copper and lead have been useful in so many ways. With growth of human population, industrialisation, enormous increase in vehicular traffic and use of chemical fertilizers and pesticides, our environment has been contaminated with heavy metals. Heavy metals may also be present in water bodies, under ground water in some areas which are close to the minerals which occur in nature. In our country, several villagers in West Bengal are suffering

from sores and ulcers due to arsenic poisoning from drinking water. In Minamata, a fishing village in Japan, mercury poisoning hit many villagers.

Heavy metals cannot be removed rapidly from the environment. These are not detoxified (made harmless) by organisms through metabolic activity (biochemical reactions within the body). Heavy metals are also not broken down into simpler products by microorganisms. In other words, they are non-biodegradable. Thus heavy metals accumulate in the environment and have harmful effects on organisms causing heavy metal pollution.

Toxicity depends on the type of heavy metal. Those metals which are insoluble pass through the body without causing much harm. Some metals cause immediate sickness and they are the most dangerous as they do not leave time for treatment. However the worst are those metals which bioaccumlate* and biomagnify** in the food chain, for example, mercury.

* bioaccumulate organisms have a capacity to neutralise some toxins while others are retained in their tissues known as bioaccumulation.

** biomagnify concentration of some toxic metals gradually increase in successive trophic level through food chain. Such biomagnification may make food unsuitable for consumption and thus causes sickness.

Intext Questions 35.1

1. Name any two toxic heavy metals.

   .....

2. Define a heavy metal.

   .....

3. Mention an anthropogenic source of heavy metal pollution.

   .....

35.5 Molecular Basis of Heavy Metals Toxicity

Toxicity in organism is caused by three general mechanisms although the toxic effects on physiology of different organisms. Some of the common mechanisms are :

(i) Metals have strong affinity for sulphur. Sulphydryl (S-H)group is present in some enzymes in the organisms. The metal attaches to S–H group and blocks the active site of the enzyme. The normal functioning of the enzyme gets impaired.

(ii) A heavy metal may displace an essential ion during synthesis of biomolecule. The biomolecule loses its activity e.g. Pb replaces Ca of the bone, making it fragile.

(iii) Metal ions may cause conformational changes in enzymes rendering them inactive.

Toxicity is also caused when the metal blocks the defence proteins of the body which fight infections of organism. Also certain forms of heavy metals can pass through cell membrane protecting vital organs like the brain or foetal membranes in a pregnant mother and cause harm.

35.6 Effects of Pb, Hg and Cd Contamination

All trace elements have some toxic effects if ingested for a long enough period or at sufficiently high concentrations. We shall now study the sources of contamination and toxic effects of three heavy metals - lead, mercury and cadmium.

Lead : Lead is a very severe pollutant.

Occurance: 0.1% by weight of Pb occurs in the earth's crust in rocks and soil. It occurs naturally in some plants.

Anthropogenic Sources : Human activities have increased the quantity of lead in the environment. Some such anthropogenic sources are:

(i) Soil forms a dumping ground for Pb from mining, smelting, sewage and agricultural sludge;

(ii) From vehicle exhausts: Tetraethyl lead is mixed with petrol for improving efficiency of intemal combustion engines of vehicles. Fuel evaporating from fuel tank and carburetters and unburnt fuel from mopeds and motor bikes release compounds of Pb through automobile exhausts and it accumulates as dust.

(iii) Lead is also released from industries and reaches the soil from accumulating as dust. Pb goes into potable (fit for human consumption) water from lead pipes and lead storage tanks. Pipe joints also have Pb in soldering which may be carried alongwith waterflow.

(iv) It is released from lead acid batteries.

(v) Paints like the yellow lead chromate used for marking roads deteriorate and enter the environment.

(vi) Pottery glazers use lead compounds for glazing. This forms a source of Pb contamination.

Properties : Some of the characteristics of lead pollutants are discussed below:

(i) Lead and its compounds accumulate in the soil. They also bio-accumulate but do not biomagnify.

(ii) They are non-biodegradable.

(iii) They remain in the soil and enter food chain when crops take them up.

Entry into human body: Lead has damaging effects on the human system. It can enter the body in the following ways:

(i) Lead enters human body from canned food and beverages.

(ii) Pb leaches from glazed pottery in acidic media or at high temperatures.

(iii) Surma used in the eyes also has lead.

(iv) Compounds of lead coming out of automobile exhausts enter human through inhalation and skin contact. Children in busy streets show a high lead level in blood. Even breast milk of women living on footpaths have a high lead content.

(v) Lead oxides settle in the soil, in water, on fruits and leafy vegetables from where these easily enter the food chain and reach human body.

Toxic effects of Lead: Lead is a severe toxicant. Some of the toxic effects of lead are discussed below:

(i) After getting into human body lead reaches blood and through circulation gets into soft tissues. Lead however ultimately deposits in the bones replacing calcium,

(ii) Absorption of lead is higher in children and in people suffering from calcium deficiency. It can bioccumulate and remain in the human body for many years. During old age and illness lead moves back from bone to blood to increase level of lead in blood and becomes toxic: It may reach the brain and cause brain damage, convulsion and behavioural disorders.

(iii) Lead interferes with haemoglobin formation and causes anaemia due to deficiency of haemoglobin. Lack of haemoglobin may further cause kidney and brain damage.

(iv) Acute toxicity of lead maybe fatal.

Mercury

Metallic mercury is relatively inert and nontoxic. On inhalation it reaches blood and them to central nervous system and causes severe damage.

Occurance : Mercury is present in the earth's crust. It also reaches the environment from volcanic gases and evaporation from oceans. Mercury exists as metallic mercury, inorganic salt, and organic methyl mercury. Soil bound mercury is converted into dimethyl mercury by the action of anaerobic bacteria. Mercury is also present in traces in fossil fuel and minerals. Plants take up mercury from soil and release it as mercury vapour during transpiration as mercury is volatile.

Anthropogenic Sources: Mercury has been in the environment for long even earlier than the 20th century. It reaches the environment in the following ways:

(i) While extracting gold and mercury from the ores.

(ii) Burning of fossil fuels releases mercury vapours into the environment. Coal in India has a high mercury content. If low grade coal is used in thermal power plants, mercury which has a high vapour pressure and high combustion temperature escapes into the atmosphere and condenses as dust particles.

(iii) Wastes from paper, plastic, caustic soda and chlorine industries release mercury into the environment.

(iv) Mercury compounds are used as fungicides or pesticides because of their toxicity and thus finds ways to environment.

(v) Electrical appliances : Mercury is excellent conductor of electricity, so it is used in electric switches, lamps and batteries. Such appliances are potential source for the release of mercury vapours.

Entry of Hg into plants, animals and humans : Hg reaches plants from soil when it is taken up by roots. Plants may also take up mercury vapour from air through the stomata (pores) on the leaves. In animals mercury reaches the tissues as it is soluble in fatty acids

which form the components of cell membranes of all cells of a tissue. Mercury bio-accumulates and biomagnifies. In humans it enters through the food chain, mainly through the consumption of fish. In fish it is present in the form of methyl mercury.

Toxic effects of Mercury: People in Japan suffered from a disease called Minamata disease due to consumption of mercury poisoned fish.

Minamata disease: In Japan in 1953 mercury poisoning occurred due to consumption of fish which had died of Hg poisoning. Mercury had contaminated the water where it had reached as effluent of a vinyl chloride (ingredient of plastic) factory. Fishermen living in coastal areas of Minamata Bay had eaten the dead fish. They suffered from Minamata disease, whose symptoms were weakened muscles, impaired vision, mental retardation, paralysis and death.

Mercury is non toxic when swallowed but if inhaled in its volatile form it enters brain through blood stream, causing damage to nervous system. Hence mercury should be handled in a well ventilated room and cleaned up if spilt. Hg ions have affinity for sulphur and cause harm by attaching to sulphur containing amino acid of proteins. Hg ions also bond with haemoglobin and other blood proteins especially those containing sulphydryl groups.

Most toxic to humans are the organo-mercury compounds especially methyl mercury as it disolves in fatty tissues and bio-accumulates and bio-magnifies. Microorganisms convert high levels of inorganic mercury into the organic derivatives like dimethyl mercury. Methyl mercury compounds are very toxic because of the following reasons :

(i) These compounds can reach brain and interfere with transmission of nerve impulses

(ii) These compounds can cause permanent damage to the central nervous system of foetus of pregnant mothers.

(iii) These compounds also cause increased loss of water from kidney and ultimately causes to death.

Cadmium : Cadmium is highly toxic metal.

Occurrence : The natural sources of cadmium are volcanic activity, spray from oceans and forest fires.

Anthropogenic Sources : Humans activity add more cadmium to atmosphere than natural sources. Coal mining, non-ferrous metal mining, refineries, coal combustion, burning of refuse (water matter) iron and steel industries and phosphate fertilizers are main sources of cadmium. Tobacco containing cadmium is finely dispersed in air when released with cigarette smoke. Cadmium is chemically very similar to zinc. It also occurs with zinc minerals.

Entry of Cadmium into Plants, Animals and Humans

Plants requiring zinc pick up cadmium along with zinc as cadmium occurs alongwith Cadmium, thus enters the food chain. Cadmium in present in from potatoes, wheat, rice and other grains. Sea food also have a high level of cadmium.

Humans get cadmium in their system from tobacco smoking and from tobacco chewing Tobacco leaves absorb cadmium from irrigation water.

Individuals living near and working for mines and smelters processing zinc and electroplating face a heavy risk of cadmium toxicity. Cadmium is soluble in water and reaches the humans working in zinc mines.

Toxic Effects of Cadmium: Cadmium is a cumulative poison. It is retained in the body for a long time and causes

(i) hypertension (high blood pressure),

(ii) heart ailments

(iii) kidney damage

(iv) destruction of red blood cells

(v) damaged mitochondrial function of cells.

Cadmium resembles zinc chemically Ca^{2+} and Cd^{2+} share the same charge and have similar sizer. It may therefore replace zinc in enzymes and thus destroy their catalytic activity. In Japan, people got a bone disease "itai itai" where Ca^{++} of bones were replaced by Cd^{++}.

35.7 How to Prevent Heavy Metal Toxicity

To save human lives and other organisms from disasters due to toxic effects of heavy metals, preventive measures need to be enforced. Government of India has set up in January 1985, a separate Ministry of Environment and Forests which looks into the issues of environment. Several non-government agencies are also busy educating people about the ill effects of metal and other pollution and the ways to prevent it.

Industries have been asked to take steps for proper disposal of industrial waste. Special devices have been designed for removal of effluents. The government has decided to take penal action against industries which do not install proper devices and dump waste in the rivers or on soil. Efforts are underway to gradually phase out the use of leaded petrol. Newly manufactured cars have been designed to use lead-free petrol. Catalytic converters have been designed for using lead free petrol in the old cars.

35.8 How to Remove Metal Pollution

It is very difficult to remove metal pollutants as metals are present in a very low concentration, There are however, two ways of designing systems for removal of metal pollution:

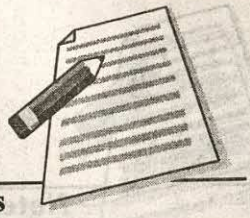
(i) design process for removal of one metal or

(ii) design one process which removes several metals.

For rivers and sediments contaminted by heavy metals; the following have been suggested.

(i) Place layers of uncontaminated clean soil over contaminated sediment so that the metal containing sediment may not get washed away by rivers.

(ii) Treating with $CaCO_3$ which increases pH of the sediment and immobilises heavy metals.



(iii) Limestone, gypsum, iron sulphate and activated charcoal can be used as detoxifying.

(iv) Using water Plants such as *pistia* and *hydrilla* which pick up mercury from water bodies and help in reducing mercury-pollution.

Intext Questions 35.2

(1) What causes Minamata disease?

.....

(2) List three sources of lead pollution.

.....

(3) Name the mercury derivative which is very toxic to human.

.....

(4) Mention two water plants by which mercury pollution can be reduced?

.....

What You Have Learnt

- Heavy metals occur in earth's crust in traces. Their excess in the environment harm living organisms.
- Heavy metal is one whose density exceeds 5g cm^{-3}.
- A trace metal occurs in 1000 ppm or less in the earth's crust.
- In nature, heavy metals accumulate in soil by natural phenomena like volcanic activity, weathering of rocks, action of wind, water etc.
- The anthropogenic sources for metal pollution are mining, smelting, fossil fuel burning, discharging agricultural, industrial and domestic wastes, auto exhausts etc.
- Heavy metals reach ecosystem from soil and water and enter humans and other organisms through food chain.
- Heavy metals cannot be removed rapidly from environment as they are neither detoxified nor biodegraded. Instead some of them bioaccumulate and biomagnify.
- At the molecular level, metals become toxic as they impair the proper functioning of enzymes by attaching to S-H group of the enzyme or causing conformational changes in them. A heavy metal may displace an essential ion.
- Pb is released from industries or from Pb pipes or leaded petrol. It causes nervous disorders.
- Hg comes into environment from plastic, paper, chlorine industries. Methyl mercury: is especially dangerous to humans which they might get through food chains. It causes nerve damage and kidney disorders. In Japan Hg toxicity caused Minamata disease.

- Cadmium is toxic. It enters the environment through coal mining, coal combustion, burning of refuse, fertilisers etc. Cd causes hypertension. In Japan Cd caused a disease itai-itai.
- Heavy metal toxicity can be prevented by proper disposal of industrial effluents, use of unleaded petrol and educating masses about toxicity of metals. Metals already accumulated can be removed by using aquatic plants which take them up or by covering contaminated sediments with clean soil.

Terminal Exercise

1. List five human activities which release heavy metals into the environment.
2. How do heavy metals reach the ecosystem?
3. Relate a molecular, mechanism by which a heavy metal becomes toxic.
4. How does cadmium accumulate in the environment? What kind of effect does it have on human body?
5. List five sources of lead pollution. Mention two of its adverse effects.
6. Mention two toxic effects of mercury contamination.
7. Write a note on Minamata disease.
8. How can heavy metal pollution be checked?

Answers to Intext Questions

35.1

1. Any two from Cd, Hg, and Pb
2. A heavy metal is one whose density is greater than 5g cm^{-3}.
3. Anyone from, mining, auto exhaust, paper, plastic, paint factories.

35.2

1. Hg
2. Refer to section 35.2
3. Methyl mercury
4. Pistia, Hydrilla

Notes

36

RADIOACTIVE POLLUTION

In the previous lesson we have discussed the harmful effects of some heavy metals and how to reduce these effects. In this lesson we will discuss about the radiations which are the cause of radioactive pollution. These radiations are emitted by radioactive decay of unstable heavy atoms nuclei. Exposure of these radiations can cause damage to living cells and environment.

Concern for radioactive pollution increased after the discovery of artificial radioactivity, development of nuclear weapons and installation of nuclear reactors for generating electricity. In this lesson, we shall discuss the possible threat to human health and environment due to nuclear radiations both from natural and anthropogenic (man-made) sources. Methods for the safe disposal of nuclear waste materials will also be discussed.

Objectives

After reading this lesson, you will be able to :

- list various radioactive sources;
- account for the release of radioactive products resulting from nuclear waste and nuclear accidents;
- enumerate the ill-effects of radioactive radiation on human body;
- list the various preventive measures of radioactive pollution and
- list the various regulations regarding safety measures for radiation exposure.

36.1 Radiations and Radioactivity decay

Radiation is energy travelling through space. Energy can be transported either in form of electromagnetic waves (radiations) or a stream of energetic particles, which can be electrically charged or neutral.

These radiations are of two types :

(1) Non-ionizing radiations

(2) Ionizing radiations

Non-ionizing radiations are the electromagnetic waves of longer wavelength from near ultraviolet rays to radiowaves. These waves have energies enough to excite the atoms and molecules of the medium through which they are moving, causing them to vibrate faster. These do not have enough energy to ionize them.

Ionizing radiations are the electromagnetic radiations having high energy, such as short wavelength ultra violet radiations, *x*-rays and gamma rays. The energetic rays like (α, β and γ etc.) produced in radiocative decay can cause ionization of atoms and molecules of the medium through which they pass and convert them into charged ions.

For example in water molecule, it can induce reaction that can break bonds in proteins, DNA and or other importants molecules.

Alpha (α), beta (β) and gamma (γ) radiations are produced by the process called **radioactive decay.** The unstable nuclei decay spontaneously and emit these radiations. These rays (radiations) can affect some other non-radioactive atoms to become radioactive (unstable) and give out radioactive radiations.

36.2 Radioactive Pollution and their Sources

Living organisms are continuously exposed to a variety of radiations called background radiations. If the level of the radioactive radiations increases above a certain limit it causes harmful effects to living beings. This harmful level of radiations emitted by radioactive elements is called **radioactive pollution**.

There are two sources of radiation pollution, namely natural sources and arthropogenic sources.

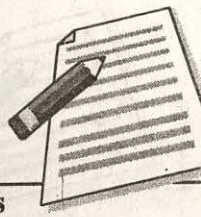
36.2.1 Natural Sources of Radiation

(i) Atomic radioactive minerals are one of natural sources of radioactive pollution. During mining of uranium, radon gas is constantly released into the air. The parent of radon-222 ($t_{½}$ = 3.82 days) is radium 226 which has a half-life of 1602 years. Radium-226 is widely distributed in rocks, sediments and soils along with isotopes of uranium. Radioactive radiations from these natural sources are known as natural or background radiation.

(ii) Cosmic rays are high energy ionizing electromagnetic radiation. The cosmic rays originate from the stars in our galaxy by virtue of nuclear reactions primarily in their cores. The cosmic rays are constantly reaching the earth from outer space.

(iii) Naturally occurring radioisotopes such as radon-222 found in soil in small quantity is another source of radioactive radiations.

(iv) Radioactive elements which like uranium, thorium, radium, isotopes of potassium (K-40) and carbon (C-40) occur in the lithosphere.Potassium-40 contributes radioactivity to all potassium containing systems in the soil. Crops grown on such soil contain radioactive elements like carbon-14 and potassium-40. Water gets contaminated with various radionuclides when it runs through soils and rocks containing radioactive minerals.



We live in an environment of natural radiations there is a certain amount of radioactive radiations almost everywhere on the earth. These are only rarely harmful as the radiation level is generally quite low. This small level of radioactive radiation which is present everywhere is called the background radiation.

36.2.2 Anthropogenic Sources of Radiation

The following human activites add to the source of radioactive pollution:

(i) **Diagnostic medical applications :** Radiations are employed for diagnostic and therapeutic applications. *X*-rays are used in general radiology and CT scan. Gamma rays are used in treatment of cancer. In all these procedures we are exposed to varying doses of radiations.

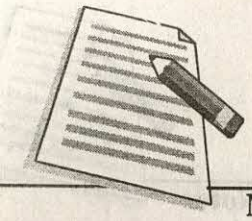
(ii) **Nuclear Tests :** Nuclear explosion tests especially when carried out in the atmosphere are a major cause of radiation pollution. It is responsible for increasing the background level of radiation throughout the world. During atmospheric nuclear explosion tests, a number of long-lived radionuclides are released into the atmosphere. This **radioactive dust** (also known as **radioactive fall out**) gets suspended in air at a height of 6 to 7 km above the earth's surface and is dispersed over long distances by winds from the test site. These radionuclides often settle down by rain and get mixed with soil and water. From there they can easily enter the food chain and finally get deposited in the human body where they cause serious health hazards. Some of the radioactive isotopes given off during nuclear test affect the human body.

India exploded its nuclear device (equivalent to 12 kilotons of Tri Nitro Toluene) in an underground tunnel at a depth of 107 meters in the Thar desert near Pokharan in 1974. No radioactivity is said to have been released into the surroundings. Again in May, 1998 India conducted nuclear tests without any fall out of radioactivity into the surroundings.

(iii) **Nuclear Reactors :** Radiations may leak from nuclear reactors and other nuclear facilities even when they are operating normally. It is often feared that even with the best design, proper handling and techniques, some radioactivity is routinely released into the air and water.

However, dangers of radiation leakage are from possibility of accidents that could result in the release of radioactive material which raises the level of radioactive (ionizing) radiations. Such accidents took place at the 'Chernobyl nuclear power plant' in USSR in 1986 and at the 'Three Mile Island Power Plant' in USA in 1979.

The accidents of 'Three Mile Island' plant in Middletown (U.S.A.) in 1979 and at Chernobyl nuclear power plant (U.S.S.R.) in 1986 were the worst disasters in the history of nuclear power industry. In both incidents, a series of mishaps and errors resulted in the overheating of the nuclear core. In both cases radiation was released in the atmosphere. The leakage from the 'Three Mile Island' nuclear reactor has been claimed to be very low with no immediate injuries to workers or people. But the leakage at Chernobyl was very heavy causing death to many workers and radiation was spread over large areas spread all over Europe.



Notes

Nuclear fission converts some tadioactive fuel in the reactors to some other radioactive fragments. These reactions produce a lot of heat and therefore the core of the reactor containing fuel rods cooled by water circulation to avoid a meltdown of the fuel rods. If a meltdown happens by accident, it will release a large quantities of highly dangerous radioactive materials into the environment. In order to avoid this type of very serious mishap nuclear reactors are designed to have a number of safety features and it is very unlikely that a reactor would blow up.

Although a core meltdown is highly unlikely, but it is possible. For example, the loss of coolant due to some material failure, would allow the reactor core to overheat and eventually meltdown the fuel rods. Another possibility is the build up of some gas or steam inside the reactor vessel which would blow off the top and release large clouds of radioactive materials in the atmosphere resulting in death and injury to thousands of people.

(iv) **Nuclear explosions :** Nuclear explosions are a serious source of radiations hazard. The effects of atomic explosions in Nagasaki and Hiroshima are still not forgotten.

(v) **Nuclear Wastes**

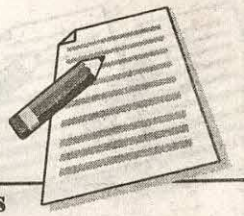
When uranium-235 nuclei split in a nuclear reactor, they break into fission products

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n + \text{Energy}$$

which are also highly radioactive. Since one uranium atom splits into two radioactive products, there is a doubling of the number of radioactive atoms on the earth. Furthermore. uranium-235 has a half-life of more than 700 million years. Some of its fission products have shorter half-lives and decompose much faster than uranium and emit higher levels of radiations. There is no method by which we can increase or decrease the rate of decay of these products. The wastes of nuclear reactor emit dangerous radiations for thousands and thousands of years. Since it is not possible to destroy these radionuclides, they must be stored somewhere on this earth in order to ensure least harm to humans.

Plutonium-239 is another nuclear waste. The plutonium-239 isotope is produced as a by-product during uranium fission. It is an alpha particle emitter and has a long half-life of 24000 years. After about 1000 years or more, the main radioactivity from fuel rods of the nuclear reactors will be from plutonium and other such heavy elements, since by then most of the other nuclides produced in fission and having much shorter half-life will have decayed to a large extent. Plutonium is one of the deadliest poisons known. Plutonium does not occur naturally on earth. This element is produced either in nuclear reactors or in nuclear weapons programme. The plutonium produced today will have to be taken care of for thousands of years by future generations. The general approach in dealing with radioactive wastes is to concentrate and contain as much radioactivity as possible. Effluents containing only very low level of radioactivity are allowed to be discharged into the environment.

Radon can diffuse through rocks and soils into the atmosphere. Once the radon reaches the atmosphere it can be breathed in. The transformation into lead is very significant because the solid radioactive particles are trapped in the lungs and are acutely harmful.



(vi) Nuclear material processing. Many radioactive minerals are processed to extract radioactive metals. Several compounds of radioactive elements are also produced and processed, for various uses. All those who handle these materials are at a greater risk of man-made radioactive pollution.

Intext Questions 36.1

1. What are ionizing radiations?

   .....

2. Name any of the two sources of radioactive pollution in nature.

   .....

3. Name three man-made or anthropogenic sources of radioactive pollution.

   .....

4. What were the two accidents in the past which led to high radioactive leakage.

   .....

5. What happens when a neutron strikes uranium-235?

   .....

36.3 Biological Effects of Ionizing Radiation on the Human Body

In the last few decades, number of people being exposed to ionizing radiation has increased tremendously, especially people involved in the mining of uranium ores, patients treated with γ-radiations and technical people using *X*-rays and other radioactive isotopes. Before the dangers of radiation on human body were known, workers dealing with radioactive materials were careless and suffered from various types of cancer. Early workers who used phosphorescent radium paint on the dials of watches suffered from bone tumors in 1920s.

Exposure to any type of ionizing radiation (α and β particles, γ-rays and *X*-rays) can prove harmful and even lethal. The two types of effects are :

(i) **genetic** and

(ii) **nongenetic** or **body damage.**

In **genetic damage,** genes and chromosomes get altered. Its effect may become visible as deformations in the offsprings (children or grandchildren). Alterations or breaks in the genetic material, that is DNA (deoxyribonucleic acid)- the molecule containing genetic information, is called **mutation**. In **nongenetic effects**, the harm is visible immediately in the form of birth defects, burns, some type of leukemia, miscarriages, tumors, cancer of one or more organs and fertility problems.

Table 36.1 : Effects of radioactive radiation on living beings

Type of radiation	Effect on the body
α-particles	Generally they cannot penetrate the skin. But if their sources is inside the body, they can cause damage to bones or lungs.
β-particles	Can penetrate the skin but cannot damage the tissues. They can cause damage to skin and eyes (cataract).
γ-radiation	Can easily penetrate the body and pass through it. They cause damage to cell structure.
X-rays	Can travel very far and pass through the body tissues except bones. They can cause damage to the cells.

36.4 Radiation Doses and Radiation Effects

The biological damage caused by the radiation depends upon the following factors :

(i) the time of exposure

(ii) the intensity of radiation

(iii) the type of ionizing radiation (i.e. its penetration power)

(iv) whether the radiation is emanating from outside or inside the human body.

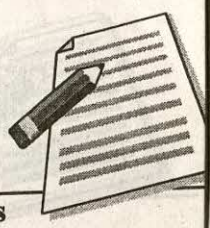
On account of these factors the absorbed (or simply doses dose) designated as D, of the radiation to be the amount of energy deposited into a region of the body divided by the mass of the portion of the body that absorbed the radiation.

The MKS unit of absorbed dose is 'gray' (Gy), thus one gray is one joule of energy deposited per kg of mass. More traditional unit of absorbed doses is **radiation absorbed dose** (rad). One rad is equivalent to 0.01 Gy. Biological damage caused by a particle depends not only on the total energy deposited but also on the rate of energy loss per unit distance traversed by the particle. For example, alpha particles do much more damage per unit energy deposited than do electron (β-particles). This effect is represented by the quality factor Q taken 0 for electron and 20 for alpha particle.

The biological impact is specified by the human equivalent dose H, which is the product of the absorbed dose D and the quality factor Q : H = QD. The MKS unit of the human equivalent dose is called the sievert, Sv.

A traditional unit of human equivalent dose is the rem, which stands for radiation equivalent in man, 1 rem = 0.01 Sv.

At low doses such as what we receive every day from background radiation (< 1m rem) the cells repairs the damage rapidly, At higher doses (upto 100 rem), the cell might not be able to repair the damage, the cell may either be changed permanently or die. Cells



changed permanently may go on produce abnormal cells when they divide and may become canerous.

Table 36.1 shows the effects of different radiations on the body. These radiations reach human system from natural and anthropogenic sources.

Alpha (α) and beta (β) particles can cause burns to skin on high level of exposure from outside but they cannot penetrate the skin to cause internal damage. However, if a radioactive isotope which can emit alpha or beta particles is inhaled or ingested in the body the particles can then cause serious damage to nearby tissues. They may affect the replication of cells and induce tumor formation. The damage inside the body from beta particles is lower than that from the alpha particles of the same energy. Gamma (γ) rays and high energy neutrons are so much penetrating that they pass through the body easily and can cause cellular damage both from outside or inside the body.

Rapidly growing tissues of embryo are very sensitive and therefore pregnant women should avoid exposure to radioactivity and *X*-rays unless they are very essential. Although the medical use of *X*-rays may involve very low levels of radiation but even such exposures if carried out frequently can result in a significant increase in the dose of ionizing radiation and involves definite risks. The use of radio-isotopes and gamma ray irradiation for cancer treatment can lead to fairly high dosages of radioactivity.

An increase in the altitude, where an individual lives determines the dose received from cosmic radiation. For example, an increase in an altitude of 2000 meters doubles the dose of radiation due to cosmic rays from outer space. The effect of radiation may be immediate or delayed.

Intext Questions 36.2

1. What is radiation absorbed dose (rad)?

   .....

2. What as the effect of radiations on human body?

   .....

3. What are the factors or which the biological damage by radioactive radiations depends?

   .....

36.5 Preventive Measures from Nuclear Radiation

The following preventive measures my be adopted to reduce the effects due to both natural and artificial radiations:

(i) Atomic explosions should not be carried out in the atmosphere.

(ii) In nuclear reactors, closed cycle coolant system may be employed, so that no radiation leakage through coolant can take place.

(iii) Radioactive wastes generated by nuclear reactors or from nuclear weapons programme must be disposed in a manner that they will do the least harm. First, the wastes may be stored at some place temporarily to allow for the initial, very intense, radioactivity to die down by natural decay. Nuclear wastes should always be sealed

in double-walled tanks so that no leaks may take place. In the second stage, some useful isotopes generated during fission in the reactors may be recycled in reprocessing plants. Finally, a permanent storage space for the wastes in geologically stable underground deep mines should be established It has been suggested that these wastes may be stored till the wastes are reduced to the same radioactivity level as that of a natural uranium mine.

(iv) Production and use of radioisotopes should be minimum and only for very essential use because radioisotopes once produced cannot be destroyed by any means except by the passage of time.

(v) The number of nuclear installations should be minimised so as to limit the emission of radio-pollutants.

(vi) Fission reactions should be minimized.

(vii) In nuclear mines, wet drilling may be used and tailings properly sealed and protected for radiation leakage.

(viii) Industrial wastes contaminated with radionuclides be disposed off carefully in specially built tanks.

(ix) Working places where radioactive emissions are possible should have high chimneys and good ventillation system.

(x) In areas where there is a risk of radon leakage from underground. radon concentrations be monitored and protection measures be installed in buildings and homes.

36.6 Regulations Regarding Safety Measures

The executive agency for all activities related to atomic anergy is Department of Atomic Energy (DAE) which was established in 1954. The sites for nuclear installations are chosen with safety parameters in view. A number of physical barriers are designed which checks any significant escape of radiation from the reactor. The radiation dosage received by workers are monitored on a monthly basis. The Atomic Energy Regulatory Board (AERB) has fixed the dose limit to 30 millisievert (mSv) for workers. This is in agreement with the limit set up by International Commission on Radiological Protection (ICRP).

The atomic Energy Regulatory Board, an autonomous body of Atomic Energy Commission, carries out all regulatory and safety functions as envisaged under the Atomic Energy Act, 1962 covering all establishments of Department of Atomic Energy. It is also empowered to take decision with regard to site selection, design, construction and commissioning, operation, etc. of all nuclear installations.

Intext Questions 36.3

1. How the radioactive waste management should be done?

   .....

2. How can we safeguard ourselves from radiation originating from tailings?

   .....

3. What the dose limit is fixed for the workers of nuclear installations?

   .....

What You Have Learnt

- Nuclear radiations are emitted in the atmosphere through natural sources and man made sources.
- Radiations due to natural sources are due to uranium and other radioactive elements which occur in nature and on disintegration may yield other radioactive isotopes. The prominent amongst them is radon-222 gas.
- Man-made sources of radiation include :
  (i) medical diagnostic tests using radioisotopes
  (ii) nuclear tests conducted in the atmosphere
  (iii) nuclear reactors for research and power
  (iv) nuclear accidents
  (v) nuclear explosion
  (vi) nuclear waste
  (vii) production and handling of nuclear material.
- Ionising radiations can cause mild to very serious effects on the health of humans on exposure and may even lead to death. Some ill effects continue to pass on to future generations.
- Various steps have been suggested by which radiation leakage can be minimized.

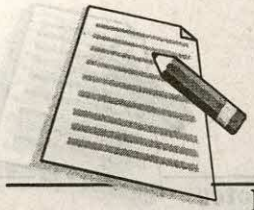
Terminal Exercise

1. Do the cosmic rays act as radioactive pollutant?
2. Which type of radiations are damaging for human health?
3. Define the term 'Background Radiation'?
4. What are the different man-made sources of radiation pollution?
5. What are the effects of ionizing radiation on human health?
6. What are the preventive measures for radiations?

Answers to Intext Questions

36.1

1. These are the electromagnetic radiations of short wavelength or charged particles (like α and β-particles) which can cause ionization of atoms or molecules.
2. Weathering of minerals, cosmic rays from outer space, radioactive elements occurring in nature. (Any two)
3. Nuclear waste, nuclear reactors, nuclear accidents.
4. The accident of 'three mile Island' in Middle Town (U.S.A) in 1979 and at Chernobyl nuclear power plant (U.S.S.R) in 1986.



Notes

5. Uranium-235 splits into two fission products with the production of three neutrons and lot of energy. The split products are also radioactive. The reaction is known as a nuclear fission reaction.

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n + \text{Energy}$$

36.2

1. Radiation absorbed dose (rad) is the unit of adsorbed dose. It is defined as the amount of energy deposited into a region of the body divided by the mass of the portion of the body that absorbed the radiations.

2. Both the effects are observed on human body : (i) gentic and (ii) non-genetic (body damgage). In genertic effects are observed in offsprings. In non-genetic effects harms are visible as burns, miscarriages, leukemia, cancer, etc.

3. Biological damage by radiatins depends upon :
   (i) the time of exposure;
   (ii) the intensity of radiation;
   (iii) the type of ionizing radiations and
   (iv) radiations emanating from outside or inside of body.

36.3

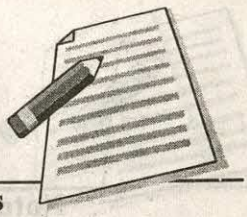
1. Radioactive waste should be disposed of properly and storing should be done carefully in double walled tanks, storing of these waste should be done till it comes to its natural level of radioactivity.

2. Refer to section 36.5.

3. Dose limit fixed for workers is 30 m Sv.

MODULE - VIIIB
CHEMISTRY AND INDUSTRY

32. Petrochemicals
33. Polymers
34. Dyes, Paints and Pigments
35. Drugs and Medicines
36. Building Materials



Notes

32

PETROCHEMICALS

In the first five modules of this course in chemistry you have learnt about the conceptual framework of this vast subject. In the first two modules you studied the chemistry of the elements of s,p,d and f blocks and of organic compounds respectively. In this optional module you would learn about some important industrial chemicals.

The first lesson of this module deals with petrochemicals, the chemicals derived from petroleum. Petrochemicals include a very vast range of chemicals. You would learn about their meaning, classification, production and application. This lesson also deals with soaps and detergents and rocket fuels. Many of them are the important byproducts obtained from petrochemicals. In the next lesson you would learn about polymers another vast class of molecules which are integral part of our day to day life.

Objectives

After reading this lesson you will be able to :

- define petrochemicals;
- explain different generations of petrochemicals with flow sheet diagram;
- cite various examples of petrochemicals;
- list uses of various petrochemicals;
- write about the status of petrochemicals in India;
- distinguish between soaps and detergents;
- explain types of detergents;
- list advantages and disadvantages of detergents over soaps;
- explain cleaning action of soaps and detergents;
- classify rocket propellants;
- give examples of chemicals used in various classes of rocket propellants and
- write about the status of propellants with reference to Indian Space programs.

32.1 What are Petrochemicals?

You are aware, petroleum is a complex mixture of hydrocarbons formed by the decomposition of fossil remains. It exists as a liquid (crude oil), gas (natural gas) or as solids (oil shales) and is found deep underground or below seabed.

You have also studied that petroleum is refined to several useful fractions, which are used as fuel (LPG, petrol, diesel, etc.) or lubricants. About 10% of the petroleum is used to prepare a range of chemicals called petrochemicals, we may define, petrochemicals as a group of chemicals produced directly or indirectly from the hydrocarbons of petroleum or natural gas.

Some gaseous hydrocarbons are also obtained as a by product during petroleum refining. These hydrocarbons may contain one to five carbon atoms, for example, methane, ethane, propane, butane, iso-butane, pentane, etc. Methane (CH_4) is also a major hydrocarbon component of natural gas, which occurs in association with petroleum.

At one time these gaseous hydrocarbons were of almost no use and the only way to dispose them was to burn them. With passage of time these gaseous hydrocarbons have found important use as starting material to produce a large variety of petrochemicals. Today, the demand of petrochemicals and the materials derived from petrochemicals is so great that we need to deliberately convert higher hydrocarbons to smaller gaseous hydrocarbons by the process of cracking.

The list of petrochemicals is endless. Some important petrochemicals are methyl alcohol, ethyl alcohol, acetaldehyde, acetic acid, acetic anhydride, acetone, benzene, toluene, xylenes, phenol, vinyl chloride, etc. some of these can be used directly or as raw materials for the manufacture of other useful products. These are used to manufacture a vast variety of useful materials like solvents, adhesives, antifreezes, synthetic rubbers, synthetic fibers, nylon, polyester, plastics, synthetic detergents, rocket fuels, etc.

Since every area of human activity makes use of petrochemicals or the materials made from petrochemicals, our life without petrochemicals would be very different and less comfortable.

32.2 Classification of Petrochemicals

The nature of petrochemical industry is very complex. The journey from petroleum to useful end products is long and there are many steps in the process. Let us try to understand feed-stock, primary and intermediate petrochemicals and the end products in the context of petrochemicals.

Feed Stock

The starting material used for the production of petrochemicals is called feed stock. There are two common feed stocks for the manufacture of petrochemicals; these are :

1. Natural gas
2. Naphtha and reformed naphtha

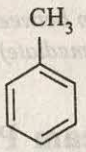
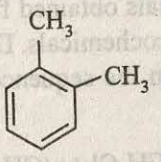
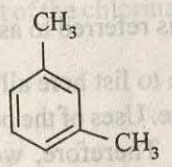
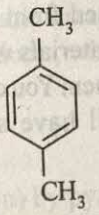
You would recall that natural gas occurs in nature in association with petroleum. The major hydrocarbon component of natural gas is methane. Naphtha is a fraction obtained during refining of petroleum.

Some countries or industries prefer to use natural gas while some other use naphtha as a starting material (feed stock) for the production of petrochemicals. The choice for the use of natural gas or naphtha as feed stock by a particular country or industry depends upon the availability of a particular feed stock or the availability of technology for the manufacture of petrochemicals.

32.2.1 Primary Petrochemicals

Primary petrochemicals are the molecules obtained from the feed stock and are used to manufacture petrochemical intermediates. Since the feedstock consists of natural gas, naphtha and reformed naphtha, these give different primary petrochemicals. The primary petrochemical obtained from these are compiled in Table 32.1.

Table 32.1 : Important Primary Petrochemicals from different feed stocks

S.No.	Feed Stock	Primary petrochemicals	Formulae
1.	Natural gas	Ethene	$CH_2=CH_2$
		Propene	$CH_3-CH=CH_2$
		Ethyne	$CH\equiv CH$
2.	Naphtha	Ethene	$CH_2=CH_2$
		Propene	$CH_3-CH=CH_2$
		Butadiene	$CH_2=CH-CH=CH_2$
3.	Reformed Naphtha	Benzene	
		Toluene	
		o – xylene	
		m-xylene	
		p-xylene	

32.2.2 Intermediate Petrochemicals and Derivatives

The petrochemicals obtained from primary petrochemicals by chemical reaction are called (secondary) intermediate petrochemicals. Petrochemicals are also refered to as first generation petrochemicals and second generation petrochemicals, First generation petrochemicals are converted to second generation petrochemicals. These intermediate petrochemicals may be put to some use or these may be further processed to get derivatives of petrochemicals by a chemical reaction or a series of reactions to get products for other end uses.

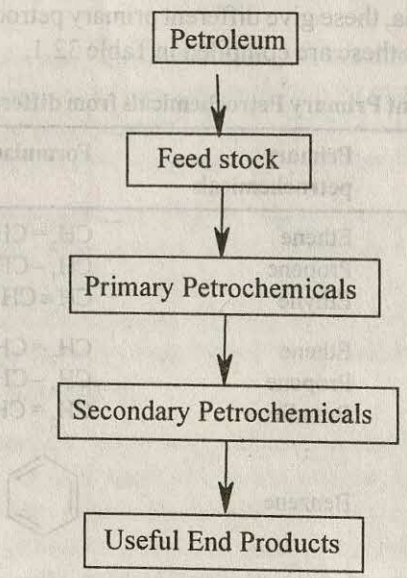


Fig. 32.1 : *Relationship between petroleum, feedstock, primary petrochemicals, secondary (intermediate) petrochemicals and useful end products.*

32.2.3 Down Stream Petrochemicals

The petrochemicals obtained from a given feedstock by a series of reactions are called down stream petrochemicals. Down stream means that a particular petrochemical comes at a later stage in the sequence of chemicals produced. For example in the following reaction.

$$CH_4 \rightarrow CH_3Cl \rightarrow CH_3OH$$

Methyl alcohol is referred to as a down stream petrochemical.

It is not possible to list here all the petrochemicals and the chemical processes used for their manufacture. Uses of the petrochemicals are very diverse and it is impossible to give a complete list. Therefore, we are giving methods of manufacture of some of the petrochemicals and their derivatives along with their uses. We will discuss in detail the petrochemicals obtained from methane and ethene as two typical examples. While for some other starting materials we will give, only the names of the petrochemicals which can be obtained from them You can learn more details in higher classes or in more advanced books. Here you will have some idea about the vastness and importance of the petrochemicals.

Intext Questions 32.1

1. Define petrochemicals

.....

2. What do you understand by the term feed stock with reference to petrochemicals?

.....

3. Write names of two feed stocks used in petrochemicals industry.

.....

4. What do you understand by the term down stream petrochemical? Explain with an example.

.....

5. Methane is converted into methyl chloride then methyl chloride is converted to methyl alcohol. In this case identify the first generation and second generation petrochemical.

.....

32.2.4 Petrochemicals from Methane

Methane is the major hydrocarbon component of natural gas. CNG is the compressed natural gas and LNG is the liquified natural gas. Moreover, methane is also obtained in large quantities as a by product of petroleum refining.

The major petrochemicals produced from methane are:

1. Chlorinated products
2. Unsaturated hydrocarbons
3. Carbon black
4. Hydrogen
5. Methyl alcohol

1. Chlorinated products of methane

Methane is chlorinated to get methyl chloride (CH_3CI), methylene chloride (CH_2CI_2), chloroform ($CHCI_3$) and carbon tetrachloride (CCI_4). Most of the chlorinated products of methane are used as a solvent.

$$CH_4 + CI_2 \rightarrow CH_3CI + CH_2CI_2 + CHCI_3 + CCI_4$$

2. Unsaturated hydrocarbons

Methane is cracked (by pyrolysis) with the help of suitable catalysts to get ethylene, propylene and acetylene. These are used to get other products, which will be discussed later.

3. Carbon black

Methane is converted into carbon black (a form of carbon) by pyrolysis (cracking) and

hydrogen is obtained as a by product. Carbon black is used as a black pigment in manufacture of black printing ink and in rubber tyre industry.

$$<CH_4 \xrightarrow{\Delta} C + 2H_2>$$

4. Hydrogen

Hydrogen obtained by pyrolysis of methane is used for the manufacture of ammonia gas. Ammonia is used as a raw material for manufacture of urea (a fertilizer), ammonium nitrate and several other products.

5. Methyl alcohol

Methane is converted into methanol (methyl alcohol, CH_3OH) by catalytic oxidation.

$$<CH_4 + O_2 \xrightarrow{\text{Catelyst}} CH_3OH>$$

(methanol)

Methyl alcohol (methanol is further oxidized to get formaldehyde. Formaldehyde is an important raw material for number of useful products, for example phenol-formaldehyde resins (bakelite). Methyl alcohol is an important industrial solvent.

$$<CH_3OH \longrightarrow HCHO>$$

(formaldehyde)

32.2.5 Petrochemicals from Ethylene

Ethylene is obtained by pyrolysis of natural gas or from naphtha by cracking. Ethylene is an unsaturated hydrocarbon and has a carbon-carbon double bond. Therefore, ethylene is very reactive and can be converted to a variety of petrochemicals and useful end products.

The major petrochemicals produced from ethylene are :

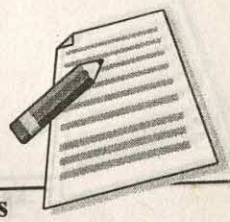
1. Ethyl alcohol
2. Ethylene oxide
3. Ethylene glycol
4. Dichloroethane
5. Vinyl chloride
6. Polyethylene
7. Ethyl benzene

1. Ethyl Alcohol

Ethyl alcohol (ethanol) is made by hydration of ethylene. Ethyl alcohol is used as a solvent and a raw material for the manufacture of acetic acid, ethyl acetate and a large number of other useful products.

$$<H_2C = CH_2 \xrightarrow{H_2O/H_2SO_4} CH_3CH_2OH>$$

(ethanol)



2. Ethylene Oxide

Ethylene is oxidized to ethylene oxide with air or oxygen in the presence of a catalyst. It is a raw material for the manufacture of ethylene glycol, which is a starting material for the manufacture of polyester.

$$H_2C = CH_2 \xrightarrow[O_2]{\text{Catalyst}} H_2C \overset{O}{\diagdown\!\diagup} CH_2$$

(ethylene oxide)

3. Ethylene Glycol

Ethylene glycol (1,2-dihydroxyethane) is manufactured by starting with ethylene. There are several methods by which ethylene is converted to ethylene glycol.

Glycol is used as an anti freeze in automobiles. Ethylene glycol is an important starting material for the manufacture of polyester.

$$H_2C = CH_2 \longrightarrow HO - CH_2 - CH_2 - OH$$

(ethylene glycol)

4. Dichloroethane

Dichloroethane (1,2-dichloroethane) is made from ethylene by the reaction of chlorine. It is used as a starting material for several other raw materials like ethylene glycol, vinyl chloride, etc.

$$H_2C = CH_2 + Cl_2 \longrightarrow Cl - CH_2 - CH_2 - Cl$$

(1, 2-dichloroethane)

5. Vinyl Chloride

Vinyl chloride is made directly from ethylene or is made from ethylene dichloride.

$$H_2C = CH_2 + Cl_2 \longrightarrow CH_2 = CH - Cl + HCl$$

(vinyl chloride)

$$Cl - CH_2 - CH_2 - Cl \longrightarrow CH_2 = CH - Cl + HCl$$

(vinyl chloride)

6. Polyethylene

On polymerization ethylene gives polyethylene (polyethene), which is an important plastic material.

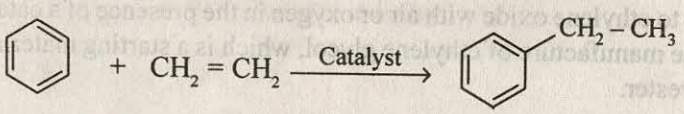
$$n \quad H_2C = CH_2 \longrightarrow -CH_2 - CH_2[-CH_2 - CH_2-]_n CH_2 - CH_2 -$$

(ethylene) **(polyethylene)**

7. Ethyl Benzene

Ethylene reacts with benzene in the presence of a suitable catalyst to give ethyl benzene. Ethyl benzene is converted to styrene. Styrene is a raw material for the manufacture of

an important plastic material polystyrene.



Ethylbenzene

32.2.6 Petrochemicals from Propylene

Propylene is obtained by pyrolysis of natural gas or by cracking of naphtha. Propylene is an unsaturated hydrocarbon.

The main petrochemicals produced from propylene are:

1. Iso-propyl alcohol
2. Polypropylene
3. Cumene (isopropyl benzene)
4. Glycerol

32.2.7 Petrochemicals from Acetylene

Acetylene (ethyne) is obtained by pyrolysis of natural gas. It is an unsaturated hydrocarbon. It has a carbon-carbon triple bond. It is highly reactive in nature.

The major petrochemicals produced from acetylene are:

1. Vinyl chloride, vinyl acetate and acrylonitrile
2. Acetaldehyde

32.2.8 Petrochemicals from Butadiene

1, 3-Butadiene is obtained from naphtha by cracking. It is a diene, that is, it has two carbon-carbon double bonds.

It is a monomer for polybutadine which is used as a substitute for natural rubber. Butadiene and styrene on polymerization give a copolymer called BUNA-S.

32.2.9 Petrochemicals from Benzene

Benzene is obtained from reformed naphtha. Naphtha is subjected to catalytic reforming (also called aromatization). In the process aliphatic hydrocarbons present in naphtha are converted to aromatic hydrocarbons.

Important petrochemicals obtained from benzene are:

1. Ethyl benzene and cumene
2. Chlorobenzene
3. Nitrobenzene
4. Cyclohexane
5. Linear alkyl benzenes (LAB)
6. Branched alkyl benzenes (BAB)

Intext Questions 32.2

1. Define primary petrochemicals.

.....

2. Mention three petrochemicals obtained from natural gas.

.....

3. What are the important petrochemicals obtained from propene?

.....

4. What are the important petrochemicals obtained from ethyne (acetylene)?

.....

5. What are the petrochemicals obtained form benzene?

.....

32.3 Status of Indian Petrochemical Industry

The Indian petrochemical industry is very small by international standards. For example, India accounts for less than three percent of the world's ethylene capacity. Ethylene capacity of India is 24 lakh tones per annum, while that of USA is 288 lakh tones per annum (2002 figures)

The common polymers manufactured in India are Low Density Poly Ethylene (LDPE), High Density Poly Ethylene (HDPE), Poly Propylene (PP), Poly Vinyl Chloride (PVC) and Poly Styrene (PS).

The main producers of polyethylene and polypropylene in India are the Reliance Industries Limited (RIL), Indian Petrochemicals Corporation Limited (IPCL), Haldia Petrochemicals Limited (HPL) and the Gas Authority of India Limited (GAIL). These industries have an advantage of having integrated petrochemical complexes. The integrated complexes have a petroleum refinery and plants producing petrochemicals at the same location. It saves on the cost of production and transportation etc. The Indian share in the production of petrochemicals has increased significantly since the commissioning of refinery based polypropylene facilities at Jamnagar by the RIL.

Till recently India could not produce enough purified terphthalic acid (PTA) and dimethyl terephthalate (DMT) to fulfill the demand of the Indian polyester industry. The production capacity was lower than the local demand. Therefore, India had to import PTA and DMT. The increase in the production of polyester in India has led to the building up of world scale plants for the manufacture of key intermediates like PTA and DMT. In India, the production of raw materials for polyester received a big boost with the commissioning of the petrochemical complexes at Patalganga and Hazira by the RIL.

The RIL, along with IPCL has a share of over 60% of the Indian polymer market for LDPE, HDPE, PP and PVC. RIL have large petrochemical complexes. The RIL also has the largest naphtha cracker in Asia. IPCL has three small to medium-sized petrochemical complexes based largely on natural gas (two medium-sized crackers using natural gas and one small-sized cracker using naphtha).

The RIL has a large share of the Indian polyester market. It has a significant position in the global market for PTA and paraxylene (a raw material for PTA). The RIL's facilities are world scale, while the plants of other companies are much smaller.

IPCL produces mono ethylene glycol (MEG) at two locations. One plant is natural gas based and the other is naphtha based. The RIL has a large naphtha based MEG facility at Hazira petrochemical complex.

32.4 Soaps and Detergents

Soaps and detergents are widely used as cleaning agents. Chemically soaps and detergents are quite different from each other. The common feature of soaps and detergents is that when dissolved in water the molecules of soap and detergent tend to concentrate at the surface of the solution or at interface. Therefore, the surface tension of the solution is reduced, it causes foaming of the solution.

Soaps and detergents lower the surface tension of the solution. Such substances are called surface-active agents or surfactants.

To sum up, soaps and detergents:

1. are used as cleansing agents
2. cause foaming of the solution
3. lower surface tension
4. molecules tend to concentrate near the surface of the solution
5. are the surface active agents
6. are the surfactants
7. can emulsify grease
8. can remove dirt, etc.

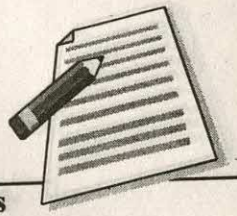
Hydrophilic and Lipophilic Parts

Both soap and detergent molecules have two parts. One part of the molecule is polar (ionic) in nature. Polar nature is due to the presence of groups like carboxylate ($-COO^-$) or sulphonate ($-SO_3^-$). The polar group is a hydrophilic group. The hydrophilic group makes soaps and detergents soluble in water. The other part of the soap or detergent molecule is non polar (nonionic) that is lipophilic. The lipophilic part (a long chain alkyl or a long chain substituted aryl group) makes the molecule oil soluble.

Depending on the nature of the hydrophilic (polar) part in the soap or detergent molecule these are classified as anionic, cationic or non-ionic type. For example, soap has a carboxylate anion therefore soap is anionic type (table 8.5.1). Synthetic detergents have sulphonate anion thus they are also classified as anionic type. Anionic types are the most common. However, cationic and non-ionic detergents are also known.

Soaps

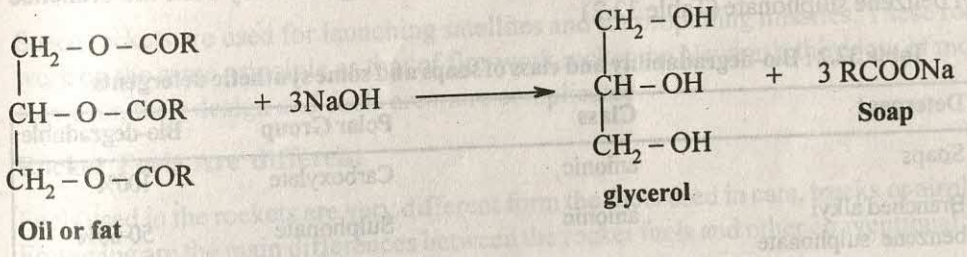
Soaps are the sodium or potassium salts of long chain fatty acids. These fatty acids are present in oils and fats in the form of glycerides. The glycerides present in oils and fats are



the esters of glycerol and long chain carboxylic acids for example palmitic acid and stearic acid.

Saponification

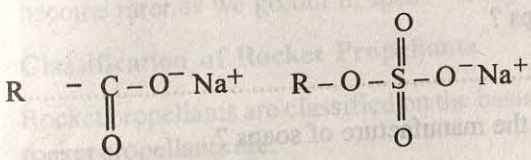
Saponification is the process of making soap. Saponification is done by hydrolysis of oils or fats (of vegetable or animal origin) with the help of alkali like sodium hydroxide (NaOH) or potassium hydroxide (KOH)



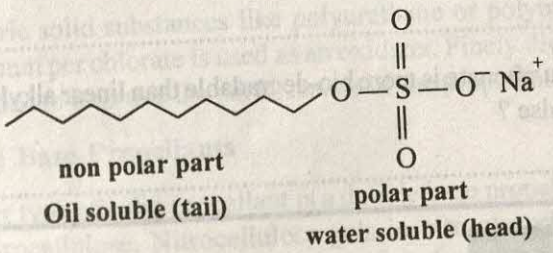
(where R= long chain alkyl group containing 11 to 17 carbon atoms)

Synthetic Detergents

Synthetic detergents are used as cleaning agents much like soaps. Chemically, detergents are sodium salts of long-chain alkyl hydrogen sulphate or sodium salts of long-chain alkyl benzene sulphonic acids. (Remember that soap is a sodium or potassium salt of long-chain fatty acid.)



Detergent molecules are similar to that of soap molecules, that is they have an oil-soluble (lipophilic) long chain of carbon atoms and a polar (hydrophilic) water-soluble part. For example, sodium lauryl sulphate ($C_{12}H_{25}$–O – SO_3Na) has a 12 carbon atom hydrocarbon like alkyl chain. The long carbon chain is oil-soluble (lipohilic) part and the sulphate is polar (hydrophilic) part that makes the molecule water-soluble. The water-soluble part is referred to as water-soluble head and the long chain of carbon atoms is referred to as oil-soluble tail.



Advantages and Disadvantages of Synthetic Detergents

The synthetic detergents are better than soaps in certain respects. Synthetic detergents can be used for washing of clothes even if the water is hard. Calcium and magnesium ions

present in hard water make corresponding salts with detergent molecules. The calcium and magnesium salts of detergent molecules are soluble in water (unlike that formed by soap molecules).

However, detergent containing branched alkyl benzene sulphonate is not completely biodegradable (Table 32.2). Soap is completely biodegradable. Therefore, excessive use of synthetic detergents is a cause of worry. The problem has been partly solved by using linear alkyl benzene sulphonate, which has better bio-degradability then the branched alkyl benzene sulphonate (Table 32.2)

Table 32.2 : Bio-degradability and class of soaps and some synthetic detergents

Detergent	Class	Polar Group	Bio-degradable
Soaps	anionic	Carboxylate	100%
Branched alkyl benzene sulphonate	anionic	Sulphonate	50-60%
Linear alkyl benzene sulphonate	anionic	sulphonate	90%
Lauryl alcohol	anionic	Sulphate	100%

Intext Questions 32.3

1. What is the active component in soaps ?

   .....

2. What are the raw materials used for the manufacture of soaps ?

   .....

3. What is the polar part in a soap molecule ?

   .....

4. What is the polar part (hydrophilic) in a synthetic detergent molecule ?

   .....

5. What is the oil-soluble (lipophilic) part in the soap molecule ?

   .....

6. Branched alkyl benzene sulphonate is more bio-degradable than linear alkyl benzene sulphonate. Is it true or false ?

   .....

32.5 Rocket Propellants

Development in rocket technology and use of better rocket propellants has enabled American astronauts to land on moon and successful spacewalk by the Russian astronauts. Launching of satellites and development of missiles has also been possible due to the advances in the rocket propellants.

India also has made considerable advances in the use and development of space technology. Indian Space Research Organization (ISRO) is the main organization for the development of space technology in India.

India has developed missiles, which can be used for the defense of our country. Moreover, India is one of those few countries that are capable of launching satellites.

Rocket Fuels

Space rockets are used for launching satellites and for propelling missiles. These rockets work on the same principle as that of fire-work rocket the Newton's third law of motion. However, their design and fuels are more complicated.

Rocket Fuels Are different

Fuels used in the rockets are very different form the fuels used in cars, trucks or airplanes. Following are the main differences between the rocket fuels and other conventional fuels.

1. A rocket fuel must occupy small space in the rocket.

If the fuel occupy a large space then the rocket will become very big and heavy. It may not be able to attain high velocity to go out high in the space.

2. A rocket must carry enough supply of oxygen (or oxidizing agents) to burn the fuel.

A space rocket has to pass through areas in space where there is little or no oxygen (air become rarer as we go out in space - away from earth).

Classification of Rocket Propellants

Rocket propellants are classified on the basis of their physical state. The major classes of rocket propellants are:

1. Solid propellants
2. Liquid propellants
3. Hybrid propellants

1. Solid Propellants

Solid propellants are the most commonly used rocket propellants. These are also known as solid composite propellants. It is a mixture of a solid fuel and a solid oxidizer.

Polymeric solid substances like polyurethane or polybutadiene are used as fuel. Solid ammonium per chlorate is used as an oxidizer. Finely divided aluminum or magnesium is also added to improve the performance of the propellant.

Double Base Propellants

Another type of solid propellant is a double base propellant. It consists of nitroglycerine and nitrocellulose. Nitrocellulose gels in nitroglycerine to set as a solid mass. Both nitrocellulose and nitroglycerine have enough oxygen in their nitro groups to support the combustion of fuel. This do not need any separate oxidizer.

Solid propellants on ignition can be made to burn at a predetermined rate. The problem with solid propellants is that once ignited they will continue to burn and it is not possible to stop ignition or to change the rate of ignition.

2. Liquid Propellants

Liquid propellants use a combination of a liquid fuel and a liquid oxidizer.

Liquid propellants, in general, give a higher thrust than solid propellants. Switching on and off the flow of the propellant can control the thrust. Controlling the rate of flow of the fuel can also control the thrust.

Liquid propellants are of two types. These are:

(a) Bi-liquid propellants

(b) Mono-propellants

(a) Bi-Liquid Propellants

Bi-liquid propellants contain a liquid fuel and a liquid oxidizer. The liquid fuel and liquid oxidizer are kept in separate tanks. These are taken to the ignition chamber through separate pipelines.

If liquid oxygen is used as an oxidizer and liquid hydrogen is used as a fuel then the very low temperatures are to be maintained. Therefore, special engines are used to pump them through the pipes. The engines, which can work at extremely low temperatures, are known as **cryogenic engines.** Very few countries have the capability to manufacture cryogenic engines.

The most commonly used liquid fuels are kerosene, alcohol, hydrazines, liquid hydrogen, etc. The commonly used oxidizers are liquid oxygen, nitric acid, nitrogen tetraoxide (N_2O_4).

(b) Mono-Propellants

Mono-propellants contain a single chemical compound. On decomposition or ignition these produce a large volume of gases.

Hydrazine (N_2H_4) can be used as a mono-propellant. Hydrazine on catalytic decomposition produces nitrogen and hydrogen gas. Some other examples of monopropellants are nitro methane, methylene nitrate, hydrogen peroxide, etc.

3. Hybrid Propellants

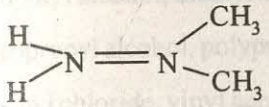
Hybrid propellants are those, which have a solid fuel and a liquid oxidizer. For example, a mixture of acrylic rubber is used as a fuel and liquid nitrogen tetraoxide (N_2O_4) as an oxidizer.

Propellants used in Various Rockets

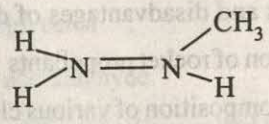
Different fuels have been used in different space programs. Some rockets may use different fuels in the different stages of ignition.

In India SLV-3 (Space Launch Vehicle) and ASLV (Augmented Space Launch Vehicle) rockets have used composite solid propellants.

The PSVL (Polar Satellite Launch Vehicle) used solid propellants in the first and the third stages. In the second stage liquid propellant nitrogen tetraoxide (N_2O_4) as oxidizer and unsymmetrical dimethyl hydrazine (UDMH) as a fuel is used. In the fourth stage N_2O_4 and monomethyl hydrazine (MMH) is used as a fuel. India is one of the six nations, which have PSLV capability. The other five nations are the US, Russia, China, France and Japan.



Unsymmetrical dimethyl hydrazine
UDMH



mono methyl hydrazine
MMH

You often read in newspapers or watch news on TV about the development of missiles by India. India has developed various missiles and you are familiar with their names. Some of them are Bhramos, Dhanush, Prithvi-I, Prithivi-II, Prithivi-III, Agni-I, Agni-II, Akash, Trishul, Nag, Astra, etc. All these missiles need a rocket to fire them

The titan ballistic missiles use hydrazine as a fuel and nitrogen tetraoxide as an oxidizer. The space-shuttle uses liquid hydrogen and liquid oxygen combination along with solid boosters in the lower stages of the rockets. The Saturn booster rocket (used in American Space Program) derives its thrust from a bi-liquid propellant. It uses a combination of kerosene as a fuel and liquid oxygen as an oxidizer for the initial stages. Liquid oxygen and liquid hydrogen is used for the higher stages of the rocket. Russian rockets such as Proton use a bi-liquid propellant, which is a combination of kerosene and liquid oxygen. Continuous efforts are being made to find better and better rocket propellants.

Intext Questions 32.4

1. Which of the Newton's laws of motion governs the motion of rockets?

   .....

2. Why are rocket fuels different from the fuels used in automobiles?

   .....

3. What are the main classes of rocket propellants?

   .....

4. Name one oxidiser used in ballistic missiles.

   .....

What You Have Learnt

- Definition of petrochemicals
- Different generations of petrochemicals with flow sheet diagram
- Different examples of petrochemicals
- Learnt the uses of various petrochemicals
- Known the status of petrochemicals in India
- Difference between soaps and detergents

Notes

- Lyophilic and hydrophobic parts of soap and detergent molecules
- Advantages and disadvantages of detergents over soaps
- Classification of rocket propellants
- Chemical composition of various classes of rocket propellants
- Different propellants used in Indian Space programs

Terminal Exercises

1. What is the major hydrocarbon component present in the natural gas?
2. What are the common feed stocks used in the manufacture of various petrochemicals?
3. "Ortho, meta (ortho), benzene, toluene and xylenes are the primary petrochemicals". Is this statement true or false?
4. What are the major uses of the carbon black?
5. What are the major chemicals manufactured from methyl alcohol?
6. How is ethyl alcohol manufactured from ethylene?
7. How is vinyl chloride manufactured from ethylene?
8. What is the name of the polymer obtained from polymerisation of styrene?
9. Write the name of the diethanoyclic acid obtained by oxidation of para-xylene?
10. Name a primary petrochemical obtained from refinery naphtha, which is used for the manufacture of synthetic detergents?
11. Why are the fuels used in rockets different from the fuels used in homes?
12. What is a double-base rocket propellant?
13. What are cryogenic engines?

Answers to Intext Questions

32.1

1. Petrochemicals are the chemicals obtained directly or indirectly from petroleum or its fractions.
2. Starting material used for the production of petrochemicals is called feedstock.
3. Natural gas and naphtha
4. Down stream petrochemical means a petrochemical which is formed at a later stage in the sequence (order) of the chemicals produced.
5. Methyl chloride is the first generation petrochemical and methyl alcohol is the second generation petrochemical.

32.2

1. Primary petrochemicals are the petrochemicals which are directly obtained from the feedstock.

Notes

Notes

33

POLYMERS

In the previous lesson you have studied about petrochemicals, and their importance. You also studied about the uses of petrochemicals. In this lesson we continue with a detailed study of another vast area i.e. polymers. Today polymers have influenced our life style to the extent that it would not be wrong to say that we are in polymer age. Now-a-days polymers find wide range of uses starting from common household utensils, automobiles, clothes, furniture, etc., to space-aircraft and biomedical and surgical components.

Polymeric materials are light weight but can possess excellent mechanical properties and can be easily processed by different methods. In this lesson you would learn more about polymers, their types and some important-synthetic and natural polymers. In the next lesson you would learn about the colouring materials like dyes, paints and pigments.

Objectives

After reading this lesson, you will be able to :

- define the terms like monomers, polymer, homopolymer, copolymer and polymerization;
- classify polymers on the basis of their source, molecular forces and method of preparation;
- list the monomers of the polymers like natural and synthetic rubber;
- list the monomer of the polymer like polythene, polystyrene, Buna- S, PMMA, PVC, teflon, polyester, Nylon 66 and Nylon 6;
- define biodegradable polymers and
- cite examples of some biopolymers.

33.1 What are Polymers

A Polymer is a giant molecule formed by inter molecular linkage between same or different types of smaller molecules called **monomers**. If a large number of monomers (A) are linked together then the polymer is represented as $(-A_n-) - (-A-A-A-A-A)_{\overline{n}}$ is a polymer of the monomer of (A). For example, polyethene

$-(-CH_2-CH_2-)_{\overline{n}}$ is a polymer of the monomer ethylene ($CH_2 = CH_2$).

Polymer is a high molecular mass molecule formed by linking up of two or more small molecules called monomers.

Monomers are the small molecule which are capable of linking amongst themselves to form big molecules called polymers.

In some polymers more than one type of monomers combine with each other to give the polymer. For example, a polymer may be obtained from two monomers (A) and (B) viz,

$-A-B-A-B-$ or $-(-A-B-)_n$

33.1.1 Types of Polymers

Depending upon the nature of the repeating structural units (monomers), polymers are divided into two broad categories viz., homopolymers and copolymers

(a) **Homopolymer**

A polymer formed from only one kind of monomers is called homopolymer. Polyethene $-(-CH_2-CH_2-)_n$ is an example of homopolymer.

(b) **Copolymer**

A polymer formed from more than one kind of monomer units is called **copolymer or mixed polymer**. For example, Buna-S rubber which is formed from 1, 3-butadiene ($CH_2 = CH - CH = CH_2$) and styrene ($C_6H_5 CH = CH_2$) is an example of copolymer.

33.2 Polymerization

The process by which the monomers get linked up is called **polymerization**.

Polymerization is represented as :

$$M+M \longrightarrow \underset{\text{Dimmer}}{M-M} \xrightarrow{+M} \underset{\text{Trimer}}{M-M-M} \xrightarrow{+M^*} \underset{\text{Polymer}}{M-(M)_n-M}$$

where M stands for the monomer

33.2.1 Types of Polymerization

Depending upon the mode of reaction, polymerisation is classified as :

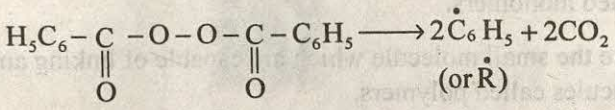
(a) addition polymerization and

(b) condensation polymerization.

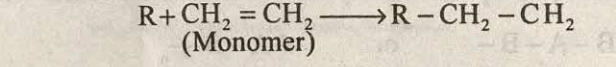
(a) Addition Polymerization : This process involves the addition of monomer units to themselves to form a growing chain by a chain reaction mechanism. It is for this reason that the process is also known as **chain growth polymerization**.

Addition polymerization is achieved by adding a catalyst (known as initiator), which provides some reactive species like free radicals.

For example benzoyl peroxide provides free radical 'benzyl' to initiate the chain polymerization reaction.



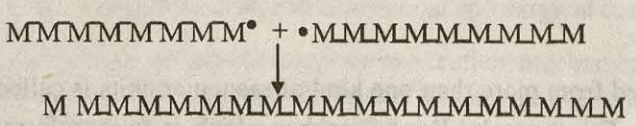
Initiation



These free radicals (R•) then attack the unsaturated monomer and form a new free radical which goes on successively adding monomers and thus grows the chain, this is called **Chain propagation** :

or M – MMMMMMMMM•

The final **termination** of the two growing chains leads to a polymer. This is called **chain termination** :

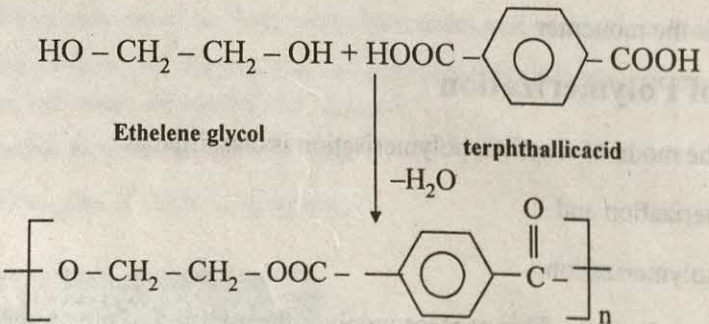


Polymer

Condensation Polymerization : In this, the monomers combine with the elimination of a small molecule like H_2O, ROH or NH_3, etc. The reaction is called (step growth) condensation polymerization and the product formed is called condensation polymer.

The process involves the elimination of by product molecules, therefore, the molecular mass of the polymer is not the integral multiple of the monomer units.

For example polyester or Terylene is a condensation polymer of ethylene glycol and terphthallic acid.



Poly (ethylene terphthalate) or (Terylene)

These two processes of making polymers have several characteristics which distinguish them from each other. These are shown in (Table 33.1).

Table 33.1 : Some differences between addition polymerization and condensation polymerization

Addition Polymerization	Condensation polymerization (Polycondensation)
1. Involves unsaturated monomere like ethylene, vinyl chloride, styrene etc.	1. Involves substances with at least 2 functional groups like ethylene glycol (2-OH groups), adipic acid (2-COOH groups).
2. Fast addition of monomers.	2. Step-wise slow addition.
3. At any instant, only monomer and polymers are present.	3. No monomer. Mixtures of dimers, trimers and tetramers etc. are present
4. Initiator is necessary to catalyse the polymerization.	4. Catalyst is not necessary.
5. No small molecules are eliminated.	5. Small molecules like H_2O, HCl, CO_2, CH_3OH are often eliminated.
6. Polymers made are, for example, polyethene, polypropylene, polybutadiene, polyvinylchloride.	6. Polymer made are, for example , terylene, nylon, Formaldehyde-resins, silicones.

Intext Questions 33.1

1. Define the terms :
   (i) Polymer (ii) Monomer

   .....

2. Write one example of each of :
   (i) Addition polymerization (ii) Condensation polymerization.

   .....

3. Differentiate between homopolymers and copolymers.

   .....

4. Write monomers of Terylene and Nylon-66.

   .....

33.3 Classification of Polymers

The polymers can be classified in a number of ways. Some of these are discussed below for a systematic investigation of their properties and uses.

(a) Classification of Polymers on the Basis of Origin.

On the basis of origin, polymers are classified as :

1. Natural polymers
2. Synthetic polymers

1. **Natural Polymers :** The polymers obtained from nature (plants and animals) are called natural polymers. Starch, cellulose, natural rubber, proteins, etc. are some examples.

2. **Synthetic Polymers :** The polymers which are prepared in the laboratories are called **synthetic polymers.** These are also called **man-made polymers.** Polyethene, PVC, nylon, Teflon, bakelite, terylene, synthetic rubber, etc. are common examples.

(b) Classification of Polymers on the Basis of structure

On the basis of structure of polymers, these can be classified as :

1. Linear polymers
2. Branched chain polymers
3. Cross-linked polymers.

1. **Linear polymers :** These are polymers in which **monomeric units** are linked together to form linear chains. These linear polymers are well packed (Fig. 33.1) and therefore, have high densities, high tensile (pulling) strength and high melting points. For example, polyethelene, nylons and polyesters are examples of linear polymers.

2. **Branched chain polymers :** These are polymers in which the monomers are joined to form long chain with side chains or branches of different lengths [Fig. 33.2]. These branched chains polymers are irregularly packed and therefore, they have lower tensile strength and melting points than linear polymers. For example, low density polyethene, glycogen, starch, etc.

3. **Cross-linked polymers :** These are polymers in which long polymer chains are cross-linked together to from a three dimensional network. These polymers are hard, rigid and brittle because of the network structure. (Fig. 33.3) bakelite, melamine and formaldehyde resin are some examples of this type.

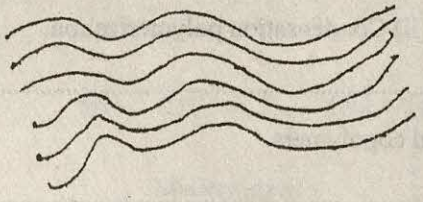


Fig. 33.1 : *Linear Polymers*

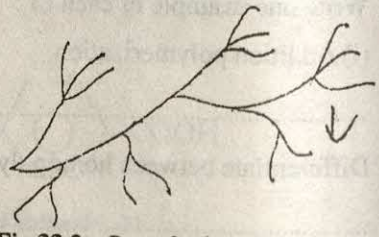


Fig 33.2 : *Branched chain polymers*

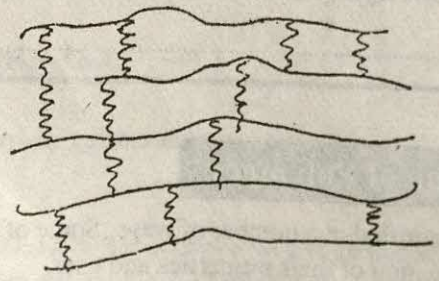


Fig. 33.3 : *Cross linked polymers*

(c) Classification of Polymers on the Basis of Method of Polymerisation

On the basis of method of polymerisation the polymers are classified as :

1. **Addition polymer :** A polymer formed by direct addition of repeated monomers without the elimination of any small molecule is called **addition polymer.** In this type, the monomers are unsaturated compounds and are generally derivatives of ethene. The addition polymers have the same empirical formula as their monomers. Examples are polyethene, polypropylene and polyvinyl chloride, etc.

2. **Condensation polymer :** A polymer formed by the condensation of two or more than two monomers with the elimination of simple molecules like water, ammonia, hydrogen chloride, alcohol, etc. is called **condensation polymer.** In this type, each monomer generally contains two functional groups. For example, nylon – 66 is obtained by the condensation of two monomers; hexa methylenediamine and adipic acid with the loss of water molecules.

$$n\,H_2N-(CH_2)_6-NH_2 + nHOOC-(CH_2)_4-COOH \xrightarrow{-n\,H_2O}$$

$$-(NH-(CH_2)_6-NH-\overset{\overset{O}{\|}}{C}-(CH_2)_4-C-O-)_n$$

nylon - 66

In this polymerization reaction $-NH_2$ group of hexamethylenediamine reacts with $-COOH$ group of adipic acid forming $-NH-CO-$ linkage with the elimination of H_2O.

$$-\overset{\overset{H}{|}}{N}-H + HO-\overset{\overset{O}{\|}}{C}- \xrightarrow{-H_2O} -\overset{\overset{H}{|}}{N}-\overset{\overset{O}{\|}}{C}-$$

linkage

Examples of condensation polymers are Nylon 66, terylene, bakelite, alkylresins, etc.

(d) Classification of Polymers on the Basis of Molecular Forces

Depending upon the intermolecular forces between monomer molecules, the polymers have been classified into four types.

1. Elastomers 2. Fibers 3. Thermoplastics 4. Thermosetting

1. **Elastomers :** In case of elastomers the polymer chains are held together by weak **van der waals forces.** Due to weak forces, the polymers can be easily stretched on applying small stress and they regain their original shape when the stress is removed. This is due to the presence of few- 'cross links' between the chains, which help the polymer to retract to its original position after the force is removed, as in vulcanized rubber.

   The most important example of elastomer is **natural rubber.**

2. **Fibres :** These are the polymers which have strong intermolecular forces between the chains. These forces are either hydrogen bonds or dipole-dipole interactions. Because of the strong forces, the chains are closely packed, giving them high tensile strength and less elasticity. These polymers can be drawn into long, thin and thread

like fibres and therefore can be woven into fabrics. The common examples are nylon-66, dacron, silk, etc.

3. **Thermoplastics :** These are linear polymers with very few cross linkages or no cross linkages at all. The polymeric chains are held by weak VANDER WAAL forces and slide over one another. Due to lack of cross linkages these polymers soften on heating and harden or become rigid on cooling. Thus they can be moulded to any shape. Polythene, PVC, polystyrene are addition type thermoplastics and Terylene, nylon are condensation type thermoplastics.

Plasticizers : Certain plastics do not soften much on heating. These can be easily softened by the addition of some organic compounds which are called **plasticizers.** For example, polyvinyl chloride (PVC) is very stiff and hard but is made soft by adding di-n-butylphthalate (a plasticizer). Some other common plasticizers are dialkyl phthalates and cresyl phthalate.

4. **Thermosetting polymers :** Usually thermosetting polymer can be heated only once when it permanently sets into a solid which can not be remelted and remoulded. Thermosetting polymers are produced from relatively low molecular mass semi fluid polymers (called polymers) which on heating develop extensive cross-linking by themselves or by adding some cross-linking agents and become infusible and insoluble hard mass. The cross links hold the molecules in place so that heating does not allow them to move freely. Therefore, a thermosetting plastic is cross linked and is permanently rigid. The common example are bakelite, melamine, formaldehyde resin, etc.

Some important differences in the properties of thermosetting and thermoplastic polymers are summerized in Table 32.2.

Table 33.2 : Distinction between Thermoplastic and Thermosetting polymers

	Themoplastic		Thermosetting polymers
1.	Linear Polymers.	1.	Cross-linked polymers.
2.	Weak van der Waals intermolecular forces and thus soften/melt on heating.	2.	Chemical cross-linking make them infusible materials. Do not melt on heating.
3.	Molten polymer can be moulded in desired shape. It can be remoulded by heating again.	3.	Cross-linking is usually developed at the time of moulding where they harden irreversibly.
4.	Examples are polystyrene, PVC, SBR, Teflon, PMMA terylene.	4.	Examples are Glyptals, epoxy polymers, formaldehyde resins.

Intext Questions 33.2

1. Define natural and synthetic polymers with examples?

.....

2. What are cross linked polymers? Give one example of this type.

.....

3. How do thermoplastic differ from thermosetting polymers?

.....

4. Arrange the following polymers in the increasing order of their intermolecular forces. Also classify them as addition and condensation polymers.

Nylon – 66, Buna-S, Polyethene.

.....

33.4 Some Commercially Important Polymers

33.4.1 Polydiens

These polymers are obtained when an unsaturated hydrocarbon with two double bonds or when a diene (2 double bond compound) is polymerized with a substituted alkene (you have studied in lesson 32 that these alkenes and diens are petrochemicals). The polymers belonging to this class are rubbers or elastomer. They can be natural or artificial. Consequently we have natural rubber and synthetic rubber.

(1) Natural Rubber : It is a polymer of unsaturated hydocarbon, 2-methyl-1, 3-butadiene also called isoprene. It is obtained from the latex of rubber trees found in tropical and semi-tropical countries such as India (southern part), Indonesia, Malayasia, Ceylon, South America, etc. The latex contains about 25-40% of rubber hydrocarbons dispersed in water alongwith stabilizer proteins and some fattyacids. It is a natural polymer and possess remarkable elasticity. It undergoes long range reversible extension under relatively small applied force. This elasticity makes it valuable for a variety of uses.

$$n\,CH_2 = \underset{\displaystyle CH_3}{\overset{\displaystyle |}{C}} - CH = CH_2 \xrightarrow{\text{Polymerisation}} \left[CH_2 - \underset{\displaystyle CH_3}{\overset{\displaystyle |}{C}} = CH - CH_2 \right]_n$$

Isoprene
2-methyl–1, 3–butadiene

Polyisoprene
(natural rubber)

In natural rubber 10,000 to 20,000 isoprene units are linked together.

Drawbacks of raw rubber.

Raw natural rubber has a number of drawbacks. For example :

1. Rubber is brittle at low temperature and becomes very soft at high temperatures. Thus it can be used only in the limited temperature range of 10-60°C
2. It is too soft to be used for heavy duty operation. Its tensile strength is only 200 Kg/cm^2.
3. On stretching, it undergoes permanent deformation.
4. Not resistant to mineral oils, organic solvents and even action of water. It has large water absorption capacity.

5. On exposure to air, it undergoes peroxidation. As a result, its durability is considerably decreased.

The desired valuable properties of plasticity, elasticity, toughness, hardness, softness, abrasion, resistance, impermeability, etc. are achieved by the process of Vulcanization.

Vulcanization of Rubber :

The wide applications of rubber are due to its property called elasticity and that is why rubber is said to be an **elastoplastic** or **elastomer.** Accidentally, in 1893, Charles Goodyears discovered that addition of sulphur to hot rubber cause changes that improve its physical properties in a spectacular manner. This process is called **vulcanization.** It is carried out by heating crude rubber in presence of sulphur or dipping it in a solution of S_2Cl_2 in CS_2.

Vulcanisation depends upon :

(i) The amount of sulphur used : by increasing the amount of sulphur rubber can be hardened

(ii) Temperature

(iii) Duration of heating.

Crude rubber is intimately mixed with about 3% ground sulphur, an accelerator and activator and then heated to about 150°C (for tyres it is 153°C). Vulcanisation is a progressive reaction and is allowed to a definite stage. The detailed mode of vulcanization process may be difficult to visualize, but probable structure of vulcanized rubber is depicted below (Fig. 33.4).

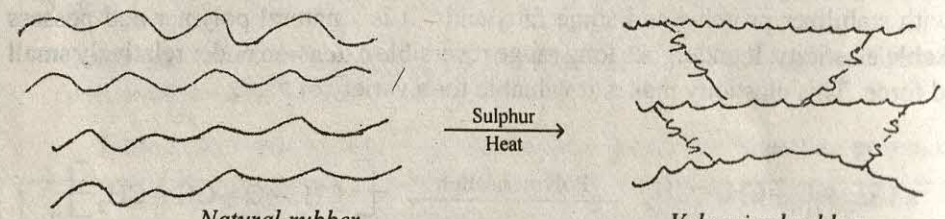


Fig. 33.4 : *Process of vulcanization of rubber*

Table 33.3 Comparison of some properties of natural rubber and vulcanized rubber :

Natural Rubber	Vulcanised rubber
1. Natural rubber is soft and sticky.	1. Vulcanized rubber is hard and non-sticky.
2. It has low tensile strength.	2. It has high tensile strength.
3. It has low elasticity.	3. It has high elasticity.
4. It can be used over a narrow range of temperature (from 10° to 60°C).	4. It can be used over a wide range of temperature (- 40° to 100°C).
5. It has low wear and tear resistance.	5. It has high wear and tear resistance.
6. It is soluble in solvents like ether, carbon tetrachloride, petrol, etc.	6. It is insoluble in most of the common solvents.

(2) Synthetic Rubbers :

Synthetic high polymers possessing similar physical properties as that of natural rubber are called **synthetic rubber.** Usually synthetic rubber is an improvement over natural rubber, specially with respect to its resistance to oils, gas, solvents, etc. Attempts to find a synthetic substitute for natural rubber began very early. **Faraday,** in 1826 concluded that natural rubber was a hydrocarbon (C_5H_8 or $C_{10}H_{16}$). Greville William (1860), obtained isoprene, a liquid from rubber. He considered rubber as a polymer of isoprene. **Fritz Hofmann** (1909), synthesized rubber first of all by the polymerization of 2, 3-dimethyl butadiene. Synthetic rubber has been produced by the polymerization of a large number of conjugated dienes resembling to isoprene. The Buna Rubber (polymers of butadiene) was prepared by Germans by the action of sodium on butadiene and that is why such synthetic rubber is known as "Buna" rubber ("Bu" from butadiene and "na" from the symbol of sodium Na). Similarly Americans made S.B.R (styrene butadiene rubber) usually known as G.R.S. Since then the synthetic rubber industry has survived alongwith the natural rubber production.

Some synthetic rubbers are made by polymerization of only one monomer, for example Neoprene is made by polymerization of chloroprene, while synthetic rubbers like Buna-S, Buna N and Butyl rubber etc. are copolymers as these have more then one monomer.

Neoprene : This synthetic rubber resembles natural rubber in its properties. It is obtained by polymerization of chloroprene.

$$n\,CH_2 = \underset{\displaystyle Cl}{\underset{|}{C}} - CH = CH_2 \longrightarrow -\left(-CH_2 - \underset{\displaystyle Cl}{\underset{|}{C}} = CH - CH_2 -\right)_n -$$

Chloroprene **neoprene**

Chloroprene is obtained by the reaction of HCl with vinylacetylene

$$CH_2 = CH - C \equiv CH + HCl \longrightarrow CH_2 = CH - \underset{\displaystyle Cl}{\underset{|}{C}} = CH_2$$

Vinyl acetylene **Chloroprene**

Neoprene is superior to natural rubber in its stability to aerial oxidation and its resistance to oils, gasoline and other solvents

Neoprene is used for

(i) making belts, hoses, shoe heals, stoppers, etc. and

(ii) manufacture of containers for storing petrol, oil and other solvents.

Buna – S:

It is obtained by polymerization of butadiene and styrene in presence of sodium metal.

$$n\,CH_2 = CH - CH = CH_2 + n\,\underset{\displaystyle C_6H_5}{\underset{|}{CH}} = CH_2 \xrightarrow[\text{Heat}]{\text{Na}}$$

butadiene **Styrene**

$$-\left(-CH_2 - CH = CH - CH_2 - \underset{\displaystyle C_6H_5}{\underset{|}{CH}} - CH_2\right)\bar{n}$$

Buna – S

In Buna – S, Bu stands for butadiene, Na for sodium and S stands for styrene. It is also called S.B.R. (Styrene Butadiene Rubber). It has slightly less tensile strength than natural rubber.

Buna-S is used for

(i) making automobile tyres.

(ii) rubber soles, belts and hoses etc.

Buna – N : It is obtained by copolymerization of two parts of butadiene and one part of acrylonitrile in presence of sodium metal.

Buna – N is hard and extremely resistant to the swelling action by oils (petrol), solvents and is resistant to heat, etc.

Uses :

(i) It is used for the manufacture of storage tanks for solvents and

(ii) For making oil seals.

Butyl Rubber : This is obtained as a result of co-polymerization of butadiene and isobutylene. It is generally carried out in the presence of small quantity of isoprene. The function of isoprene is not exactly known.

$$\underset{\text{butadiene}}{nCH_2=CH-CH=CH_2} + \underset{\text{iso-butylene}}{(CH_3)_2-C=CH_2} \longrightarrow$$

$$-\left(CH_2-CH=CH-CH_2-\underset{\displaystyle (CH_3)_2}{\underset{|}{C}}-CH_2\right)_n-$$

butyl rubber

Butyl rubbers are inert towards acids and alkalies, but have poor resistance towards petroleum products.

Uses :

(i) It is used for making inner tubes of tyres and

(ii) For making conveyor belts, tank linings and insulation of high voltage wires and cables etc.

Intext Question 33.3

1. Write the IUPAC names and structures of monomers of the following polymers :

   (i) Natural rubber (ii) Neoprene

   .....

2. What is the function of sulphur in the vulcanization of rubber?

   .....

3. What is Buna – S? How is it synthesized?

.....

4. Compare the properties (at least three) of natural rubber and vulcanized rubber?

.....

After the detailed discussion of rubbers, we shall now discuss some other commercially important polymers.

34.4.2 Polyolefins

Polyolefins is a major class of synthetic polymers made by the polymerization of an olefin (alkene) or its suitable derivative. Most of these are obtained from petro chemical industry. Polyethylene, polypropylene, PVC, Teflon, etc. belong to the class of polyolefins. Some important members of this class are discussed here with.

(1) Polyethylene or polyethene is formed by polymerization of ethylene ($CH_2 = CH_2$). It is manufactured in large quantities and is the most common polymer which you find almost every where.

Polyethene is of two types Low Density Polyethene (LDPE) and High Density Polyethene (HDPE) depending upon the nature of has branching in polymer chain and is not compact in polymer molecules. Low density polyethene has branching in polymer chains and is not compact in packing. While high density polyethere has linear chain of molecules which are packed in a more compact fashion (Fig. 33.1 and Fig. 33.2).

$$\underset{\text{ethylene}}{n\,CH_2 = CH_2} \longrightarrow \underset{\text{Polyethylene}}{-(CH_2 - CH_2)_{\overline{n}}}$$

Polyethylene is used for making pipes, insulators, packing films, carry-bags, etc.

(2) Polypropylene : The monomer units are propylene molecules. It is generally manufactured by passing propylene through n-hexane (inert solvent) containing Ziegler-Natta catalyst (a mixture of triethyl aluminium and titanium chloride)

$$\underset{\text{Propylene}}{n\,\overset{CH_3}{\overset{|}{CH}} = CH_2} \xrightarrow[TiCl_2]{Al(C_2H_5)_3} \underset{\text{Polypropylene}}{-(-\overset{CH_3}{\overset{|}{CH}} - CH_2-)_{\overline{n}}}$$

Polypropylene is harder, stronger and lighter than polyethene Polypropylene is used for packing of textile material and food, lining of bags, gramophone records, ropes, carpet fibres, etc.

(3) Teflon or Polytetrafluoro ethylene (PTFE) : The monomer unit is terafluoroethylene molecule. Teflon is prepared by heating tetra fluoroethylene under pressure in the presence of ammonium peroxosulphate. $[(NH_4)_2S_2O_8]$.

$$\underset{\text{Tetrafluoroethylene}}{n\,CF_2 = CF_2} \xrightarrow[\text{Heat, pressure}]{(NH_4)_2S_2O_8} \underset{\text{Teflon}}{-(-CF_2 - CF_2-)_{\overline{n}}}$$

Teflon is a very tough material and is resistant towards heat, action of acids or bases. It is

bad conductor of electricity. Teflon is used for coating utensils to make them non-sticking, making seals and gaskets which can with stand high pressures, insulation for high frequency electrical installations.

(4) Polyvinylchloride (PVC) : The monomer units are vinyl chloride molecules. PVC is prepared by heating vinyl chloride in an inert solvent in the presence of dibenzoyl peroxide.

$$n\ CH(Cl) = CH_2 \xrightarrow[\text{Peroxide}]{\text{Dibenzoyl}} -(CH_2 - CH(Cl))_n$$

Vinyl chloride → PVC

PVC is a hard horny material. However, it can be made to acquire any degree of pliability by the addition of a plasticizer. It is resistant to chemicals as well as heat. It is used for making rain coats, hand bags, toys, hosepipes, gramophone records, electrical insulation and floor covering.

(5) Polymethyl Methacrylate (PMMA) : Its monomer unit is methyl methacrylate.

$$n\ CH_2 = C(CH_3) - COO\,CH_3 \xrightarrow{\text{Polymerise}} -[CH_2 - C(CH_3)(COOCH_3)]_n$$

Methyl methacrylate → Polymethyl metha acrylate (PMMA)

PMMA is a hard and transparent polymer and quite resistant to the effect of heat, light and ageing. It has high optical clarity. It is used in the manufacture of lenses, transparent domes and skylights, dentures, aircraft windows and protective coatings. Its commercial names are Lucite, Plexiglass, Acrylite and Perspex.

34.4.3 Polyester

Some synthetic polymers have ester group $(-C(=O)-O-)$ in them. These are condensation polymers. The important members of this class are polyester and glyptal resins.

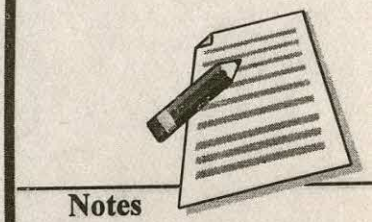
Terelene : It is a polymer obtained by the condensation reaction between ethylene glycol and terephthalic acid.

$$n\ HO-CH_2-CH_2-OH + n\ HO-C(=O)-C_6H_4-C(=O)-OH$$

Ethylene glycol + Terephthalicacid

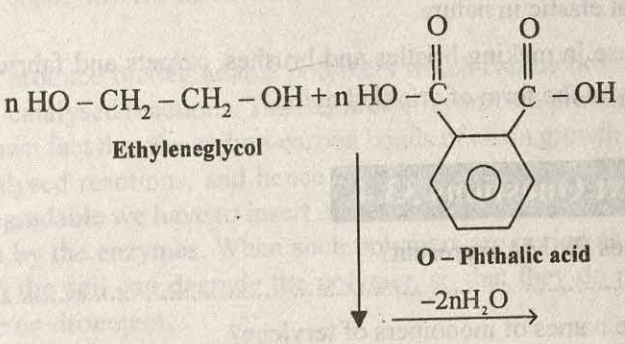
$$\xrightarrow[-2nH_2O]{425 - 475\ K} -[O-CH_2-CH_2-O-C(=O)-C_6H_4-C(=O)]_n$$

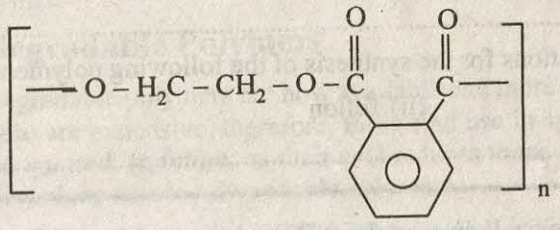
Polyester or terelene



Terelene is resistant to the action of most of the common chemicals and biological substances and also to abrasion. It has a low moisture absorbing power. As such it is widely used in making wash and wear fabrics. The polyester textile fibres made from the polymer are marketed under the trade name terelene or dacron. It is also blended with cotton and wool in clothing. It is also used in seat belts and sails. The polymer is also used in the preparation of films, magnetic recording tapes and for packing food. Dacron (and Teflon) tubes are good substitutes for human blood vessels in heart by pass operation.

Glyptal or Alkyl resin : Glyptal is a general name of all polymers obtained by condensation of di-basic acids, and polyhydroxy alcohols. The simplest glyptal is (poly ethelene glycol phthalate) which is obtained by a condensation reaction between ethylene glycol and ortho-phthalic acid.





(Poly ethylene glycol phthalate)

Glyptal resins are three dimensional cross-linked polymers. Poly (ethylene glycol phthalate) dissolves in suitable solvents and the solution on evaporation leaves a tough and non-flexible film. Thus, it is used in adherent paints and lacquers.

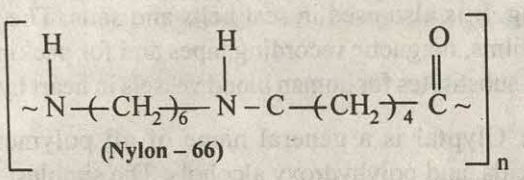
34.4.4 Polyamide

Polyamides are the polymers having amide group $(-\overset{\overset{O}{\|}}{C}-NH-)$ in them. The important polyamide is Nylon-66 which is a synthetic polymer. In nature also the polymer have amide linkages in their molecules.

Nylon – 66 : It is a polymer of adipic acid (tetra methelene dicarboxylic acid) and hexamethelene diamine

$$n\,H_2N-(CH_2)_6NH_2 + n\,HOOC(CH_2)_4-COOH \xrightarrow[\approx 525K]{\Delta}$$

Hexamethelene diamine — Tetramethelene dicarboxylic acid



(Nylon – 66)

$+ 2n\,H_2O$

Nylon – 66 (read as nylon – six-six) can be cast into a sheet or fibres by spinning devices. Nylon fibres have high tensile strength. They are tough and resistant to abrasion. They are also somewhat elastic in nature.

Nylon finds use in making bristles and brushes, carpets and fabrics in textile industry, elastic hosiery in the form of crinkled nylon.

Intext Questions 33.4

1. What does PMMA represent?

   .....

2. Write the names of monomers of terylene?

   .....

3. How is nylon - 66 synthesised?

   .....

4. Write equations for the synthesis of the following polymers :

   (i) glyptal (ii) Teflon

   .....

In this section we shall discuss about Biopolymers. (Natural Polymers)

33.5 Biopolymers

Many polymers which are present in plants and animals such as polysaccharides (starch, cellulose), proteins and nucleic acids etc. which control various life processes in plants and animals are called **biopolymers.**

(i) **Starch :** It is polymer of glucose. It is a chief food reserve of plants.

(ii) **Cellulose :** It is also a polymer of glucose. It is a chief structural material of the plants. Both starch and cellulose are made by plants from glucose produced during photosynthesis.

(iii) **Proteins :** These are polymers of **amino acids.** They have generally 20 to 1000 amino acids joined together in a highly organized arrangement. These are building blocks of animals and constitute an essential part of our food.

(iv) **Nucleic acids :** These are polymers of various nucleotides. For example, RNA and DNA are common nucleotides. These biopolymers are very essential for our life.

33.6 Environmental Problems and Biodegradable Polymers

In this section we shall discuss those polymers which will not cause any environmental pollution.

With the increasing use of polymers, the problem of disposal of waste of these products is posing alarming curse. Since most of the synthetic polymers are in the form of plastics, it is frequently used in abundance in the form of packing material and throw away bags. Since ordinary polymers do not degrade naturally by light, oxygen, water or micro-organisms, there is a serious problem of their disposal. The environmental problems caused by careless use of non-biodegradable polymers can be reduced by proper disposal of these materials and reusing them and remoulding them for other uses. Another way is to collect them and depolymerise them back to monomers. Though it has a limited application.

Another option is to produce biodegradable polymers which can be broken into small segments by enzyme-catalysed reactions. The required enzymes are produced by micro-organisms. It is a known fact that the carbon-carbon bonds of chain growth polymers are inert to enzyme catalysed reactions, and hence they are non-biodegradable. To make such polymers biodegradable we have to insert certain bonds in the chains so that these can be easily broken by the enzymes. When such polymers are buried as waste, micro organisms present in the soil can degrade the polymer, so that they do not cause any serious affects on the environment.

One of the best method of making a polymer biodegradable is by inserting hydrolysable ester group into the polymer.

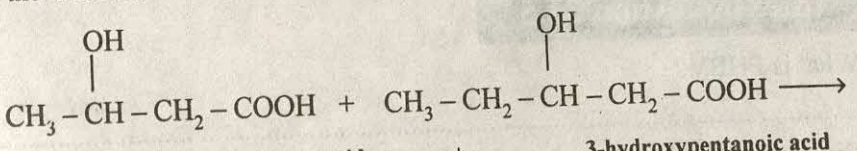
33.6.1 Some Biodegradable Polymers

A large number of bio degradable polymers are now available and more are being added to the list. However, these are expensive, therefore, these find use in special situations where cost factor can be ignored. In future, as their cost reduces these will find greater use in daily life and will replace non-bio-degradable polymers.

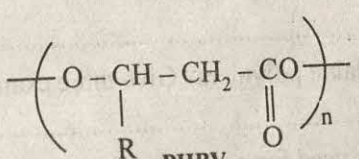
Some important biodegradable polymers are PHBV, PGA, PLA and PCL.

(PHBV) Poly-Hydroxybutyrate – co – β - Hydroxyvalerte

PHBV is a copolymer of 3 – hydroxy butanoic acid, and (3 – hydroxypentanoic acid), in which, the monomer units are connected by ester linkages.



3- Hydroxybutanoic acid + 3-hydroxypentanoic acid



PHBV

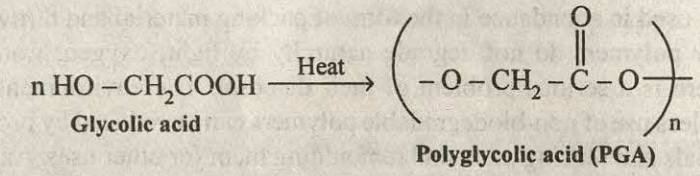
R = $-CH_3$ or $-CH_2-CH_3$

The properties of PHBV vary according to the ratio of both the acids. 3 – Hydroxybutanoic acid provides stiffness and 3 – hydroxypentanoic acid imparts flexibility to the copolymer.

(i) PHBV is used in orthopaedic devices and

(ii) In controlled drug release. The drug put in PHBV capsule is released after this polymer is degraded by enzymatic action. It can also be degraded by bacterial action.

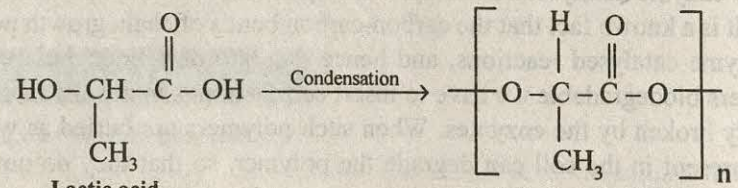
PGA Polyglycolic acid is obtained by the chain polymerization of dimer of glycolic acid, $HO-CH_2COOH$.



Glycolic acid

Polyglycolic acid (PGA)

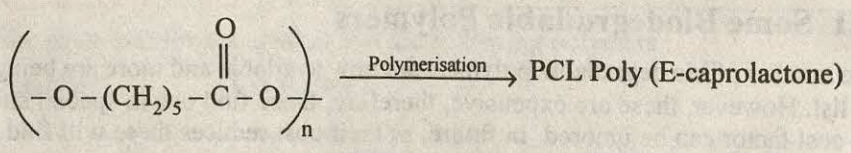
PLA Polyactic acid is obtained by polymerization of the dimer of lactic acid ($HO–CH(CH_3)COOH$) or by micro biological synthesis of lactic acid followed by the polycondensation and removal of water by evaporation.



Lactic acid

Polylactic acid (PLA)

PCL Poly (E–caprolactone) is obtained by chain polymerization of the lactone of 6 – hydroxy hexanoic acid.



Most of the biodegradable polymers find use in stiching wounds and cuts.

1. In medical goods such as surgical sutures.
2. In agriculture materials such as films, seed coatings.
3. In food wrappers, personal hygiene products, etc.

Intext question 33.5

1. What is PHBV?

   .....

2. Give two examples of biopolymers?

   .....

3. Define biodegradable polymers? Give three examples?

   .....

4. Which polymer is used for post-operative stitches?

   .....

In the following Table 33.4 we shall now give a brief account of the various commercially important polymers alongwith their structures and uses.

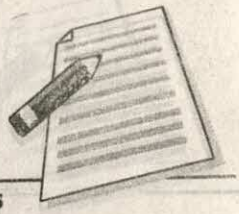
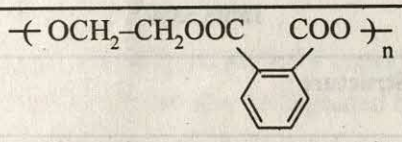
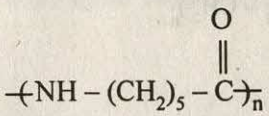
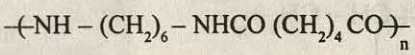
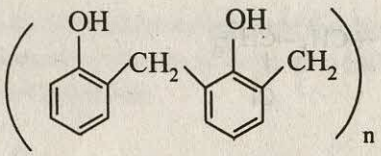
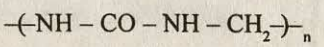
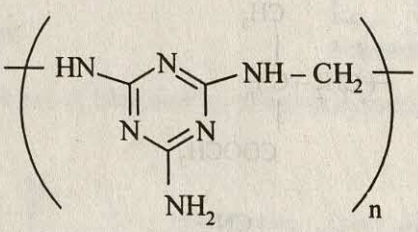
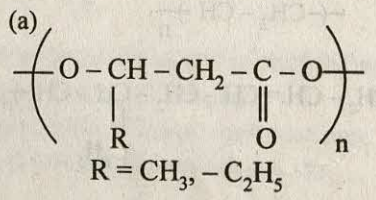


Table 33.4

S. No.	Name of Polymer	Structure	Uses
1.	Polythene	$-(CH_2-CH_2)_n-$	As Insulator, anticorrosive, packing material, household and laboratory wares.
2.	Polystyrene	$-(CH(C_6H_5)-CH_2)_n-$	As Insulator, wrapping material, manufacture of toys and household articles.
3.	Polyvinylchloride (PVC)	$-(CH_2-CH(Cl))_n-$	In manufacture or raincoats, hand bags, vinyl flooring and leather clothes.
4.	Polytetrafluoro ethylene (PTFE) or Teflon	$-(CF_2-CF_2)_n-$	As lubricant, insulator and making cooking wares.
5.	Polymethyl metha acrylate (PMMA) or Flexi glass	$-(CH_2-C(CH_3)(COOCH_3))_n-$	As substitute of glass and making decorative materials.
6.	Polyacrylonitrile (Orlon)	$-(CH_2-CH(CN))_n-$	In making synthetic fibres and synthetic wool.
7.	Styrene butadiene rubber (SBR or BuNa-S)	$-(CH_2-CH=CH-CH_2-CH(C_6H_5)-CH_2)_n-$	In making automobile tyres and footwear.
8.	Nitrile rubber (Buna-N)	$-(CH_2-CH=CH-CH_2-CH(CN)-CH_2)_n-$	In making oil seals manufacture of hoses and tank linings.
9.	Neoprene	$-(CH_2-C(Cl)=CH-CH_2)_n-$	As insulator, making conveyor belts and printing rollers.
10.	Poly ethyl acrylate	$-(CH_2-CH(COOC_2H_5))_n-$	In making films, hose pipes and furnishing fabrics.
11.	Terylene (Dacron)	$-(OOC-C_6H_4-COO-CH_2-CH_2-O)_n-$	For making fibres, safety belts, tyre cords, tents, etc.

12.	Glyptal		As binding material in preparation of mixed plastics and paints.
13.	Nylon 6		In making fibres, plastics, tyre cords and ropes.
14.	Nylon 66		In making brushes synthetic fibres, parachutes, ropes and carpets.
15.	Bakelite		For making gears, protective coating and electrical fittings.
16.	Urea formaldehyde resin		For making unbreakable cups and laminated sheets.
17.	Melamine formaldehyde resin		Formaking plastic crockery, un breakable cups and plates.
18.	Poly-β-hydroxy butyrate-co-βhydroxy valerate (PHBV)		As packging, orthopaedle devices and in controlled drug release.

What You Have Learnt

- Polymers, the high molecular mass macrosized molecules consisting of repeating units of monomers of synthetic or natural origin.
- Synthetic polymers are classified with respect to their composition, mode of poly merization and nature of molecular forces.
- Polymerization is classified into two categories (i) addition polymerization (ii) condensation polymerization.
- Addition polymers are formed by addition of large number of monomers without the elimination of any smaller molecules.

- Condensation polymers are formed by elimination of smaller molecules such as H_2O, NH_3 etc.
- Natural rubber is a linear polymer of isoprene, and is vulcanized by heating with sulphur, which forms cross link between different chains.
- Vulcanized rubber has much improved physical properties.
- Synthetic rubbers are usually obtained by copolymerization of an alkene and 1,3-butadiene derivatives.
- Synthetic polymers due to their inertness to degradation have created environmental problems.
- Since biopolymers degrade enzymatically, synthetic biodegradable polymers having functional groups such as ester, amide etc. have potential use as sutures, implants, drug release materials, are developed as alternatives. For example, PHBV, PLA, etc. constitute such materials.

Terminal Exercise

1. Explain the difference between chain growth and step growth polymerization.
2. Define the terms thermosetting and thermo-plastics. Give one example of each.
3. What is a copolymer. Give one example.
4. Differentiate between addition polymer and condensation polymer with the help of one example each.
5. What are elastomers? Give the chemical equation for the preparation of Buna-S.
6. Write the information asked for the following polymers :

   (i) Neoprene : Materials required for preparation.

   (ii) PVC : monomer unit.

   (iii) Synthetic rubber : monomer units
7. What is vulcanization of rubber? What are the advantages of vulcanized rubber?
8. Give examples of two plasticizers.
9. How are polymers classified into different categories on the basis of intemolecular forces? Give one example of a polymer of each of these categories.
10. What are biodegradable polymers? Give three examples.
11. Write the names and structures of monomers of the following polymers :

    a. Polystyrene

    b. Teflon

    c. PMMA

    d. PVC

e. PHBV

f. Polypropylene.

12. How will you prepare the following? Give chemical reaction only :

a. PVC

b. Nylon-66

c. PMMA

Answers to Intext Questions

33.1

1. (i) Polymer is a giant chain like molecule obtained by inter-molecular combinations of similar or different types of smaller molecules.

   (ii) Monomers are the low molecular mass simple molecules capable of forming inter-molecular linkage to give gaint molecules called polymers.

2. (i) Polyethene (ii) Terelene

3. (i) Hompolymers are polymers made of single monomer units, for example, polythene, polystyrene, or polybuta diene.

   (ii) A copolymer is one which is formed by the co–polymerisation of two monomers. For example, Buna (or SBR, styrene - butadiene rubber)

4. (i) Ethelene glycol and terephthallic acid

   (ii) Hexamethelene diamine and adipic acid.

33.2

1. (i) Natural polymers are found in nature, (in animals and plants) e.g. proteins and nucleic acids.

   (ii) Synthetic polymers are man-made. e.g. Nylon, polyesters and rubbers.

2. The polymers in which the linear polymer chains are cross linked to form a three-dimensional network structure are called cross-linked polymers. The common example of this type of polymer is bakelite.

3. Thermoplastics differ from thermosetting plastics in terms of mode of linkage and intermolecular forces. Thermoplastic polymer can be moulded in desired shape but thermosetting polymers set to shape on heating and can not be moulded.

4. Polyethene < Buna-S< Nylon-66

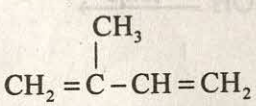
   Nylon 66 : Condensation polymer

   Buna-S : Addition polymer

   Polyethene : Addition polymer

33.3

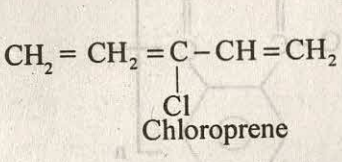
1. (i) Monomer of natural rubber is



Isoprene

2-methyl buta-1,3-diene

(ii) Monomer of Neoprene is



2-Chlorobuta – 1,3-diene

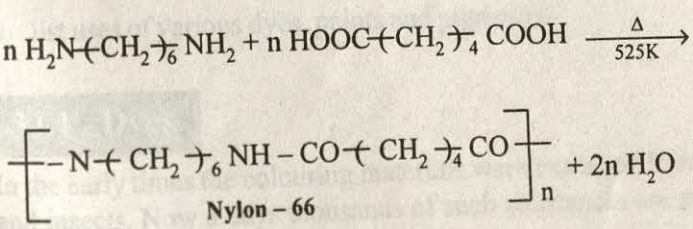
2. Sulphur makes the rubber more elastic, more ductile, less plastic and non-sticky.
3. Buna-S is obtained by co-polymerization of butadiene and styrene in presence of sodium metal. Bu stands for butadiene, na for sodium and S stands for styrene, It is also called S.B.R.
4. 1. Natural rubber is soft and sticky, but vulcanised rubber is hard and non-sticky.

   2. Natural rubber has less tensile strength while vulcanised rubber has high tensile strength.

   3. Natural rubber is soluble in solvents like ether, carbon tebrachloride, petrol etc. whereas vulcanised rubber is insoluble in all common solvents.

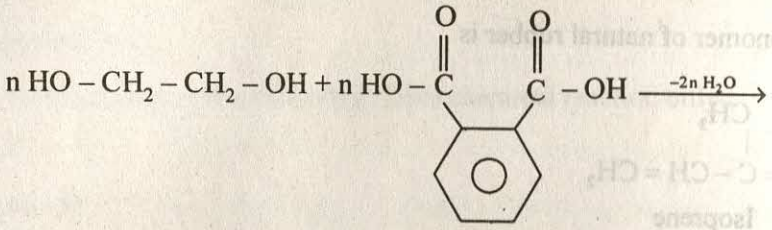
33.4

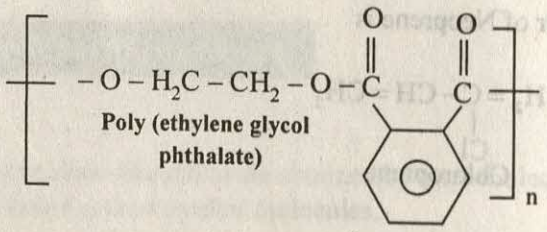
1. Polymethyl methacrylate (PMMA)
2. Ethelene glycol and terphthalic acid.
3. Nylon – 6, 6 is synthesised by the polymerisation of two monomer units adipic acid and hexamethelene diamine.



Nylon – 66

4. (i) Glyptal

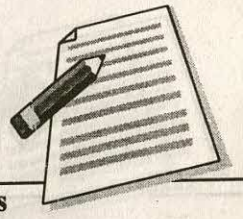




(ii) Teflon $n\ CF_2 = CF_2 \xrightarrow[\Delta,\ \text{pressure}]{(NH_4)_2S_2O_8} \leftarrow CF_2 - CF_2 \rightarrow_n$

33.5

1. PHBV is a copolymer of 3 – Hydroxy butanoic acid and 3-hydroxypentanoic acid. It is used in making capsules. It is biodegradable in nature.
2. Nucleic Acids, proteins.
3. Polymers, which are degraded by microorganisions are called biodegradable polymers. For examples, PHBV, Polyglycolic acid, Polylactic acid, etc.
4. Polyglycolic acid (PGA) and poly Lactic Acid (PLA).



Notes

34

DYES, PAINTS AND PIGMENTS

In the previous lesson you have learnt about polymers which are important industrial products. In this lesson we shall take-up another broad area of chemical industry viz; dyes, paints and pigments. These are organic or inorganic substances which find applications in imparting color to fabrics, leather, buildings, furniture and other objects. Psychologists attach special significance to the choice of colours by a person and to his/her state of mind.

Objectives

After reading this lesson, you will be able to :

- define dyes, paints and pigments;
- write formula or composition of dyes, paints and pigments;
- explain the process of dyeing and classify various dyes;
- differentiate among dyes, paints and pigments;
- classify paints and pigments;
- list various examples of dyes : Indigo, methyl orange, aniline yellow, alizarin and malachite green and etc. and
- list uses of various dyes, paints and pigments.

34.1 Dyes

In the early times the colouring materials were extracted from natural sources like plants and insects. Now a days thousands of such substances are synthesised in factories on a large scale.

Dyes are the organic compounds that are used to impart colour to textiles, foodstuffs, silk, wool and other objects. Dyes are capable of getting fixed to the fabrics/objects permanently and are resistant to the action of water, soap, light, acid, and alkalies.

Every coloured compound cannot be used as a dye. A good dye must have most of the following properties:

1. It must have a suitable colour.
2. It must be able to fix itself or capable of being fixed to the fabric from the solution.
3. When fixed, it must be fast resistant to the action of light, water, soap, detergents, etc. during washing or to the organic solvents during dry cleaning.

34.1.1 Why do dyes or dyed articles appear to have a characteristic colour?

If a molecule absorbs light in the visible region (400 nm to 700 nm) corresponding to green colour, then it will appear violet, which is the complementary colour of green. Similarily, if a dye absorbs blue colour, it will appear yellow which is the complementary colour of blue. Thus, the dyes impart colour to fabric by absorbing the complementary colour.

34.1.2 Constitution of Dyes

The colour of a compound is due to the presence of certain groups containing multiple bonds. These groups which impart colour to a compound are called **chromophores.** Some examples of chromophores are :

$-NO_2$ (Nitro), $-N = O$ (nitroso), $-N = N -$ (azo), quinonoid structures, etc.

At the same time, there are certain groups which they are not chromophores themselves but they deepen the colour when present with coloured compounds. The groups which deepen the colour of a coloured compound are called auxochromes. Some examples of common auxochromes are :

$-OH$, $-NH_2$, $-NHR$, $-NR_2$, $-Cl$, $-CO_2H$, etc.

34.1.3 Classification of Dyes

A large number of dyes are used for various purposes. These are classified on the basis of their

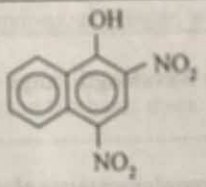
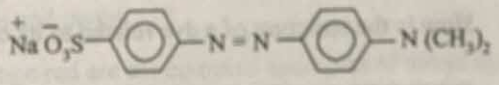
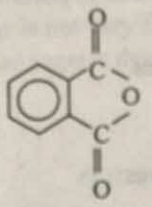
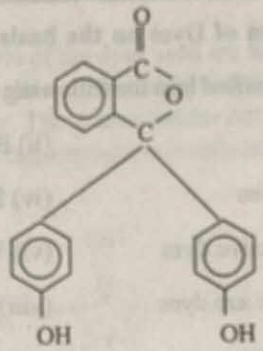
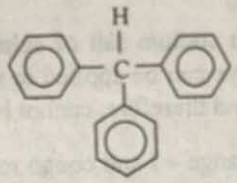
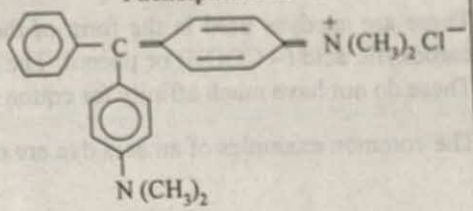
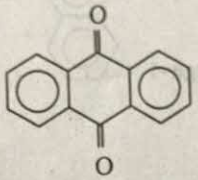
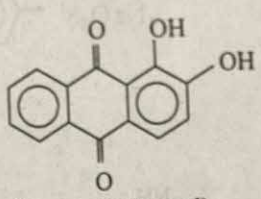
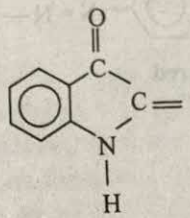
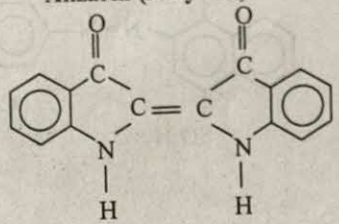
(i) constitution

(ii) application

Classification based on constitution :

Depending upon the **characteristic structural units,** the dyes, are classified as given in Table 34.1 :

Table 34.1 : Classification of some dyes on the basis of their constitution

Dye type	Characteristic Structural unit	Typical examples
(1) Nitro dyes	$-NO_2$	 Martius yellow (2, 4-dinitro-l-naphthol)
(2) Azo dyes	$-N=N-$	 Methyl orange
(3) Phthalein dyes		 Phenolphthalein
(4) Triphenyl methane		 Malachite green
(5) Anthraquinone		 Alizarin (ruby red)
(6) Indigoid		 Indigo

Intext Questions 34.1

1. Which is the structural unit of Methyl orange?

.....

2. What is the wavelength range of visible region of spectrum?

.....

3. What are complementary colours?

.....

4. How is the structure of a dye related to its colour?

.....

Classification of Dyes on the basis of their applications.

Dyes are classified into the following types on the basis of their applications.

(i) Acid dyes (ii) Basic dyes

(iii) Direct dyes (iv) Disperse dyes

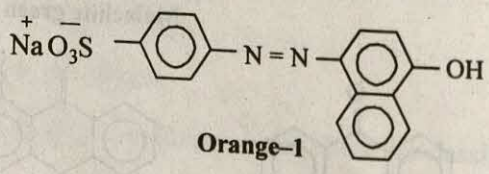
(v) Fibre reactive dyes (vi) Vat dyes

(vii) Insoluble azo dyes (viii) Mordant dyes

(i) Acid Dyes

These are azodyes used in the form of their sodium salt of sulphonic acid ($-SO_3H$), carboxylic acid (– COOH) or phenol. The dye can be applied to wool, silk and nylon. These do not have much affinity for cotton and therefore, cannot be used to dye cotton.

The common examples of an acid dye are orange – I and congo red.



Orange–I

Congo red

(ii) Basic Dyes

These dyes contain basic groups like ($-NH_2$) group or ($-NR_2$) group therefore these are called basic dyes. These dyes attack the anionic sites present on the fabrics and get attached to them. These are used to dye modified nylons, polyester, wool, cotton, leather, paper, etc.

Aniline yellow, malachite green and crystal violet are the basic dyes.

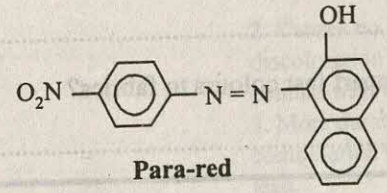
(iii) Direct Dyes

As the name suggest these dyes can be directly applied to the fabrics from their aqueous solution. The direct dyes attach to the fibre by means of hydrogen bonding. These are very effective for dying cotton, wool and rayon.

Martius yellow (Table 34.1) and congo red are the common examples of direct dyes.

(iv) Ingrain dyes

These dyes are very important because over 60% of the dyes used are **azodyes** or ingrain dyes. The fabric to be dyed is soaked in an alkaline solution of phenol or napthol and is then treated with a solution of diazotised amine. These are used for cotton, silk, polyster and nylon. The colour is not very fast because the interaction is only on the surface. For example, para-red is an ingrain dye.



Para-red

(v) Disperse Dyes

These dyes are usually applied in the form of a dispersion of finely divided dye. The dyes are disperesed in a soap solution in the presence of phenol, cresol or benzoic acid. These are used for nylon, polyster and polyacrylonitrile.

Some common examples of disperse dyes are celliton fast pink B and celliton fast blue B

(vi) Reactive dyes

These dyes attach to the fibre themselves by irreversible chemical reactions. These dyes induce fast colour on the fibres which is retained for a longer time. These dyes are used to dye fibres like cotton, wool or silk. Dyes which are drivatives of 2, 4 dichloro – 1, 3, 5 – triazine are important examples of fibre reactive dyes.

(vii) Vat dyes

Vat dyes are the well-known dyes they are insoluble in water and hence cannot be used directly for dying. Therefore, they are reduced to a colourless soluble form (leuco) in large wooden vats with a reducing agent such as an alkaline solution of sodium hydrogensulphite. Under these conditions, the leuco form develops affinity for the cellulose fibre. Then the fabric is exposed to air which oxidises the leuco (colourless) form to coloured form.

Therefore, these dyes are mainly used to dye cotton fibres. Indigo is an important example of this type (Table 34.1).

(viii) Mordant Dyes

These dyes require an additional substance (generally a metal ion) for fixing to the fibre. These are used mainly for dyeing wool. The method involves the precipitation of certain mordant material (binding agent) on the fabrics which then combines with the dye to form an insoluble coloured complex called lake. For acid dyes, metal ions are used as mordants but for basic dyes, tannic acid is used as the mordant. For example, **alizarin is a mordant dye (Table 34.1). It gives a rose red colour with Al^{3+} and a blue colour with Ba^{2+}, a brownish red colour with chromium (Cr^{3+}) and a black violet with iron mordant.**

Intext Questions 34.2

1. How are mordant dyes applied to fabrics?

   .....

2. Give an example of a Vat dye.

   .....

3. Distinguish between acidic and basic dyes?

   .....

4. Why do azo dyes not impart fast colours to fabrics?

   .....

Now we shall discuss about pigments.

34.2 Pigments

Pigments are various organic and inorganic insoluble substances, which are widely used as surface coatings. They are also employed in the ink, plastic, rubber, ceramic, paper and linoleum industries to impart colour. The pigment industry is usually regarded as associated with paints, but in fact it is a separate industry. A large number of pigments are mined or manufactured for the commercial preparation of paints. About 45 year back, white lead [$2PbCO_3 + Pb(OH)_2$], Zinc oxide (ZnO) and lithopone ($ZnS + BaSO_4$) were the principal white pigments in use while the coloured pigments consisted of Prussian blue, lead chromates, various iron oxides and a few lake colours. Composition, properties and uses of various pigments will be discussed in the next section.

34.2.1 Classification of Pigments

Pigments are broadly classified into two types :

1. White Pigments
2. Coloured Pigments

White pigments are of various types. Their composition, properties and applications are summerised in Table 34.2 :

Table 34.2 : Composition, properties and uses of some white pigments

S.No	Name of Pigment	Composition	Characteristic Properties	Application or Uses
1.	White lead $2\,PbCO_3.Pb(OH)_2$	$PbCO_3 = 68.9\%$ $Pb(OH)_2 = 31.1\%$	1. Easily applied 2. High covering power 3. Toxic in nature 4. Yellows badly on exposure to atmosphere 5. soluble in alkali and paints	In manufacture of paints.
2.	Sublimed white Lead (Basic sulphate)	$PbSO_4 = 75\%$ $PbO = 20\%$ $ZnO = 5\%$	1. High specific gravity and refractive index. 2. Slow chalking out of the film producing a rough surface.	In manufacture of paints
3.	Zinc oxide (ZnO)	$ZnO = 100\%$	1. Brilliantly white having excellent texture. 2. Causes no discoloration even in contact with CO_2 gas. 3. More durable in combination with white lead.	1. It is opaque to UV light and thus protects from uv. 2. Chalking can be prevented.
4.	Lithopone ($ZnS+BaSO_4$)	$ZnS = 28\text{-}30\%$ $BaSO_4 = 72\text{-}70\%$	1. Extremely fine and cheap pigment. 2. Good hiding power 3. Not as durable as white lead and zinc oxide	1. Widely used for cold water paints. 2. Traffic paints. 3. In floor covering and oil cloth industry
5.	Titanium dioxide (TiO_2)	$TiFeO_3$ and TiO_2 iliminite + rutile	1. High opacity and hiding power 2. High Oil absorbing capacity 3. Spreading power is almost double than that of white lead. 4. No tendency of chalking.	1. In paints 2. In Paper and textiles. 3. In other industries.

Blue Pigments

The most widely used blue pigment is ultramarine blue. There are three varieties of ultramarine namely blue, white and green. The comparative study of blue pigments is

given in Table 34.3 :

Table 34.3 : Composition, properties and uses of some blue pigments

S.No	Name of Pigment	Composition	Characteristic Properties	Application/ Uses
1.	Ultramarine Blue	White – $Na_5Al_3Si_3SO_{12}$ Green – $Na_5Al_3Si_2S_2O_{12}$ Blue – $Na_5Al_3Si_2S_3O_{12}$	1. Silicate skeleton have a potential influence on the colour 2. Colour is due to the fact that S present is in the form of polysulphide.	1. Bluing in laundering to neutralize the yellowish tone in cotton and linen fabrics
2.	Cobalt Blues	Co_3O_4 – 30-35% Al_2O_3 – 65 –70%	1. Very expensive and are not used in paints for ordinary purposes.	1. In manufacture of blue paints. 2. In making inks 3. In marking Carbon papers and carbon ribbons.

Red Pigments

Red pigments are one of the oldest-pigments. These are primarily used for inhibiting rusting of iron and steel structures. Different types of red pigments are summerised in Table 34.4

Table 34.4 : Composition, properties and uses of Red Pigments

S.No	Name of Pigment	Composition	Properties	Applications/ uses
1.	Red Lead (Pb_3O_4)	$Pb_3O_4 + PbO$	1. Bright-red powder with high specific gravity 2. Excellent covering power. 3. Inhibits corrosion	1. For primary coat on structural steel. 2. In imparting red colour to the glass for making bangles.
2.	Synthetic Iron	Fe_3O_4	1. Has dark brilliant colour 2. High covering power and tinting strength	1. Widely used in domestic paints, enamels, floors and paints.

Green Pigments

There are of two types of commonly used green pigments. Their properties, composition and uses are given in Table 34.5 :

Notes

Table 34.5 : Composition, properties and uses of Some Green Pigments

S.No	Name of Pigment	Composition	Properties	Applications/ uses
1.	Chrome Green	Cr_2O_3	1. High Power of oil absorption 2. It has disadvantages such as lack of brilliancy and opacity	As green pigments
2.	Chromium oxide or Guignet's Green	$[Cr_2O(OH)_4]$	1. Have high covering power 2. High corrosion inhibition capacity.	1.As Paint for metal surface. 2. As fast non-fading green for washable distempers.

Black Pigments

Black Pigments have good tinting strength as well as high hiding power. The common varieties are discussed in Table 34.6 :

Table 34.6 : Some Black Pigments

S.No	Name of Pigment	Composition	Properties	Applications/Uses
1.	Natural Black Oxide	Fe_2O_3 – 94-95%	1. Oil absorption power is 10-15 kg of linseed oil per 100 kg of Pigment	In making paints for priming metal
2.	Precipitated Black Iron oxide		1. High hiding Power	In cement emulsions and water paints
3.	Carbon Black/ Furnace Black		1. Increases life of paints 2. Good tinting strength. 3. Not affected by light, acids and alkalies	Used in making water proof paints
4.	Lamp Black		1. Good tinting strength 2. Resistant to high temperature	In making black pigments

Yellow Pigments

The common yellow pigments are summerised in Table 34.7 :

Table 34.7 : Some important yellow pigments

1.	Ochre	Naturally occurring yellow Fe_2O_3	Fast to light and inert to chemical action	In paint industry
2.	Chrome yellow		1. Great opacity 2. High brilliance 3. High hiding power 4. High tinting strength	In making yellow paints

Toners

Insoluble organic dyes are known as **toners** and can be used as pigments. They are quite durable and can have high colouring power. For example, para red, Hansa Yellow G (lemon yellow), Hansa yellow 10 G (Primrose yellow), toluidine toner, etc. are the various dyes that have been used as toners in pigment industry.

Metallic Powders as Pigments

The powdered form of some metals as well as some alloys are used as pigments. For example, finely powdered aluminium and bronze have been used as pigments in lacquers. Pigments containing finely powdered zinc have been used for protective coatings on iron and steel to protect them from atmospheric corrosion.

Intext Questions 34.3

1. List the green pigments, their composition and uses.

   .....

2. Write names of some blue pigments.

   .....

3. Which pigment is used to inhibit corrosion of iron and steel objects?

   .....

4. Write the composition of white lead.

   .....

5. Which porperty of zinc oxide protects the vehicles?

   .....

34.3 What are Paints?

Paints are stable mechanical mixtures of one or more pigments. The main function of the pigments is to impart the desired colour and to protect the paint film from penetrating

radiation, such as U.V. rays. The pigments and the extenders are suspended in drying oils called **vehicle.** The vehicle or drying oil is a film forming material, to which other ingredients are added in varying amounts. The paint is applied on a metal or wood surface to give it a protective coating. **Driers** promote the process of film formation and hardening. **Thinners** maintain the uniformity of the film by reducing viscosity of the blend.

The important varieties of paints are emulsion paints, latex paints, metallic paints, epoxide resin paints, oil paints, water paints or distempers, etc.

34.3.1 Constituents of Paints

The main constituents of paints are pigments, oil (vehicle) and some other materials to impart various desirable properties.

(1) Pigments

Pigments are the organic or inorganic insoluble substances which are widely used in surface coatings. They protect the film by reflecting the destructive ultra violet light, to strengthen the film.

The important pigments used for making paints are :

(i) White	:	White lead, titanium dioxide, zinc oxide.
(ii) Red	:	Red lead, Iron oxides, cadmium reds
(iii) Blue	:	Cobalt blue, Iron blues, etc.
(iv) Green	:	Chromium oxide, chrome green
(v) Black	:	Carbon black, lamp black, furnace black, etc.
(vi) Metallics	:	Copper powder, zinc dust, aluminium, etc.
(vii) Metal Protective pigments	:	Red lead, blue lead, zinc and basic lead, etc.

(2) Extenders or fillers

The extenders or fillers are the low cost materials. These are added to the paint in order to decrease the cost of the paint. These supplement the pigment in increasing the covering and weathering power of the film. Talc, china clay, gypsum, silica, barite, glass flakes, asbestos and anhydrite, etc. are used as fillers in paints.

(3) Film forming materials

The vehicle or film forming matetrials serve dual purpose in the surface coating formulations. These are usually called drying and semi–drying oils, depending on the degree of unsaturation. Linseed oil, soyabean oil, tung oil, castor oil, varnishes, casein, fish oil, etc. are used as vehicles or drying oils.

(4) Driers

Certain driers (which are oxygen carriers) have also been used in the paints, in order to accelerate the drying of the film through oxidation and polymerization. Earlier, PbO was

used as a drier, but the **Modern driers** are Co, Mn, Pb, Zn, resinoleate, linoleate and naphthenates, etc.

(5) Thinners or Diluents

Another ingredient, of paint is **thinner.** It is added to the paints to dissolve film forming materials and to dilute concentrated paints for better handling. After adding thinner, the paints may be applied more easily on the surface by brushing, spraying or dipping. **Mineral spirits** and solvents namely **turpentine,** maintains the fluidity of the freshly applied film for reasonable period of time.

(6) Antiskinning Agent

Certain **antiskinning agents** are also added to the paints in order to prevent gelling and skinning of the finished product before application of the paints by brushing, spraying or dipping. Polyhydroxy phenols are usually employed as **antiskinning agents.**

(7) Plasticizers

Plasticizers are added to the paints to provide elasticity to the film and thus prevent cracking of the paint. Chemically, plasticizers are mostly esters. Triphenyl Phosphate, dibutyl phthalate and castor oil etc. are used as **Plasticizers.**

(8) Resins :

Varnishes are used as natural or synthetic resins. Examples of natural resins are copal or resin, while that of synthetic resins are Urea formaldehyde, acrylate, vinyl or silicone resins.

(9) Binders

Binders act to fix the paint on the coated surface and provide tough, tenacious and glossy film on the painted surface.

(10) Other Compounds

Water based paints also require dispersing agents (e.g. Casein), antifoam agents, (e.g. pine oil) and preservative (e.g. chlorophenol).

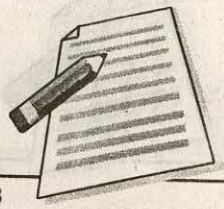
34.3.2 Paint Removers

The substances or materials which are used to remove various surface coatings or paints are called **paint removers.** Paint removers are either flammable or non-flammable.

Flammable paint removers may be liquid removers, semipaste remover and paste removers. The common **solvents** used for the purpose are alcohols such as methanol, ethanol or propanol. Hydrocarbons (benzene, toluene or xylene), acetone and ethyl acetate are also used as paint removers.

34.3.3 Special Applications of Paints

In addition to provide a thin protective layer, paints are also used for other applications some of the special uses are discussed below :



(a) Paints are extensively used as acid resisting coats.

(b) Oil bound water paints or distempers are widely used for interior decoration of walls.

(c) Coaltar products dissolved in mineral spirits have been used as protective coatings of pipes under the name bituminous paints.

(d) Bottom of ships are protected by antifouling paints which are prepared by mixing iron oxide, mercuric oxide and copper resinate dispersed in tung oil.

(e) A paint with **damp resisting properties** is prepared by mixing paraffin wax, rosin, bitumen and gutta parcha dispersed in tung oil.

Intext Questions 34.4

1. Which constituent of paint is used to decrease the cost of the paint?

   .....

2. List antifouling agents used to prepare marine paints?

   .....

3. Write three properties of emulsion paints.

   .....

4. How can we apply paints on the surfaces?

   .....

What You Have Learnt

- Dyes are coloured compounds used in imparting colour to the textiles, food stuffs, silk, wool and other objects.
- A dye is a coloured organic compound which can absorb light in the visible region of the electromagnetic spectrum (400 nm to 700 nm). The part of the light which is reflected back gives the colour of the dye i.e. complementary to the colour absorbed.
- Dyes are classified on the basis of their structures and on the method of applications.
- Pigments are various organic and inorganic insoluble substances, which are widely used in surface coatings.
- Titanium dioxide is one of the most important white pigment. Carbon black, graphite and lamp black are the chief black pigments, chromium oxide (Cr_2O_3) and Guignet's green are green pigments, Chrome yellow, strontium chromate and barium chromate are yellow pigments.
- Insoluble organic dyes are known as **toners** and can be used as pigments. They are quite durable and have high colouring power.

- Some powdered form of metals as well as alloys have also been used as pigments. Finely powdered zinc has been used for protective coating on iron and steel.
- Paints are stable mechanical mixtures of one or more pigments, extenders fillers, driers, thinners or diluents, lacquers, plasticizers, resins and binders.
- A good quality paint should have good colour, high hiding power and also have proper pigment volume concentration range(PVC) . For exterior house paint the PVC range should be 28-36%.
- Varnishes differ from paints in that they have no pigments and in varnishes a part or whole of the oil is substituted by resin.

Terminal Exercise

1. Give structure and name of a direct dye.
2. Classify dyes on the basis of their structural units.
3. Give a scheme or preparation of phenolphthalein. How does it behave under (a) acidic (b) alkaline conditions?
4. What are mordant dyes? What type of binding forces exist between the dye and the mordant?
5. Write preparation, properties and uses of the following pigments.

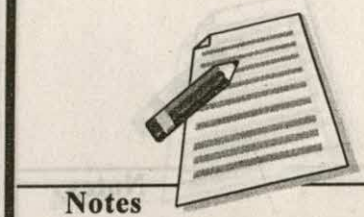
   (i) Zinc oxide

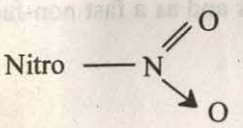
   (ii) Lithopone
6. Describe various components of paints and their significance.
7. List requirements of good paints.

Answers to Intext Questions

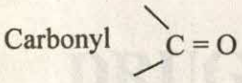
34.1

1. – N = N – group
2. The range of visible region of spectrum is [400 nm to 750 nm].
3. A dye is an organic compound which can absorb light in the visible region of the electromagnetic spectrum (400 nm to 750 nm). The part of the light which is reflected back gives the colour of the dye i.e. complementary to the colour absorbed.
4. The structure of a dye is related to its colour due to the presence of certain unsaturated groups (the groups with multiple bonds)

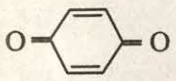




Azoxy $-N=\overset{\downarrow}{N}\rightarrow O$



Azo $-N=N-$



Polyene $-(HC=CH)_n-$

34.2

1. Mordant dyes are used mainly for dyeing of wool. The method involves the precipitation of certain substances (mordant material) on the fabrics which then combine with the dye to form an insoluble coloured complex called lake depending on the kind of mordant used (material designed to bind dye).

2. Indigo

3. Difference between Acid dyes and Basic dyes

Acid dyes	Basic dyes
1. These are azodyes usually sodium salt of $-SO_3H$, – COOH and Phenolic group.	1. These dyes contain ($-NH_2$) group or ($-NR_2$) group as oxochromes
2. The dye can be applied to wool, silk and nylon.	2. These are used to dye modified nylons, polyester, wool, leather etc.
3. Do not have any affinity for cotton.	3. Have affinity for cotton.

4. Because the interaction is only on the surface. The colour goes out on washing.

34.3

1. Green pigments are :

   (a) Chrome green

   (b) Chromium oxide

(a) Chrome green – It is chromium oxide (Cr_2O_3) and has high power of oil absorption. It is used as green pigment, known as **chrome green.**

(b) Chromium oxide – It is also called as Guignet's Green. It is a hydrated chromium

oxide $[Cr_2O(OH)_4]$. It is used as paint for metal surfaces and as a fast non-fading green for washable distempers.

2. (i) Ultramarine Blue

   (ii) Cobalt Blue and Iron Blue

3. Red lead

4. Lead carbonate, 60.2 – 68.9% and lead oxide, 31–39.9%.

5. It is opaque to white light.

34.4

1. Extenders or fillers

2. Zinc oxide, resin (Shellac), driers (Mn lineolate), vehicle (Coal-tar), diluent (pine-oil)

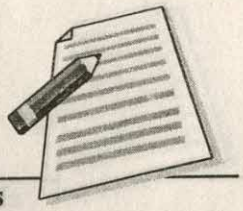
3. (i) Highly durable (ii) Impermeable to dirt

   (iii) resistant to washing

4. (i) Hand-painting or brushing

   (ii) Spraying (iii) dipping

   (iv) Roller coating (v) Tumbling



Notes

35

DRUGS AND MEDICINES

The association of mankind with pain and disease is probably as old as man himself. Humans have always been looking for remedies to overcome their pain and suffering. The earliest attempts at this, involved use of various plants. The knowledge was based on experience and was handed on from generation to generation. It is being used even today.

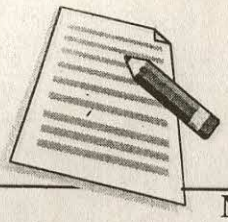
In an attempt to conquer pain and disease, a large number of synthetic chemicals have been discovered. The chemicals used as medicines are known as pharmaceuticals. Today pharmaceutical industry has grown to be one of the biggest industries in the world.

In this lesson we will try to introduce you to the area of drugs and medicines. In the process we would attempt to differentiate between drugs and medicines (though commonly used interchangeably). You will also learn about classification of medicines and other important aspects of drugs and medicines.

Objectives

After reading this lesson you will be able to :

- define drugs and medicines;
- differentiate between drugs and medicines;
- classify medicines on the basis of their action (use);
- cite examples and effects of analgesics, antipyretic, antiseptics, disinfectants, antacids, antimalarials, anaesthetics, antimicrobials (sulpha drugs and antibiotics), anti-fertility drugs, etc.;
- differentiate between analgesics and antipyretics;
- differentiate between antiseptics and disinfectants;
- explain habit forming and non-habit forming drugs;
- differentiate between broad spectrum and narrow spectrum antibiotic;
- differentiate between local and general anaesthetics;



Notes

- describe self-medication and
- alternate systems of medicine.

35.1 What are Drugs and Medicines?

When we fall ill we take some tablets, pills, injections or apply some ointments to get well. All these are collectively known as medicines. Some time we may use some parts of plants or some preparations made from herbs, minerals, animals, etc. All these substances used for the treatment or prevention of diseases, can also be called medicines. Medicines contain a single chemical or a number of chemicals in different amounts to have the desired effect.

The mode of action of the chemicals of a medicine is quite varied and complicated. In many a cases mode of action may not be fully known to us, but we continue to use them as they are useful to us.

Early man used several plants or parts of plants to cure diseases, without knowing of the chemical components, responsible for it. For example bark of willow tree was used for relieving pain (as analgesic). Later, it was found that its bark contained 2-hydroxy benzoic acid, which is closely related to acetyl salicylic acid (also known as aspirin). Parts of a plant *Rauwolfia serpentina* (Hindi name, sarpagandha) have been used in Ayurvedic drugs for the treatment of hypertension (high blood pressure). Later on it was discovered that a compound called reserpine was responsible for reducing blood pressure. Thus reserpine became the first modern medicine to control blood pressure.

In most of the cases nature led to the discovery of modern medicine. Thousands of chemists all over the world are constantly searching for better, efficient, cheaper and safer medicines.

As mentioned earlier the term drugs and medicines are used interchangeably, but there is a difference between the two. Let us try to understand the difference between drugs and medicines. The term drug is often used for preparations or formulation whose chemical components and their quantities are not known fully. These may be extracts of certain plants, herbs, animal parts or may be minerals.

The term medicine is used when the chemical composition and the quantities of various chemical components are known. Further, the effects of the chemical compounds present in a medicine and their side effects have been properly and extensively studied. The medicines are approved by the relevant governmental authorities like Drug Controller of India.

The term drug is also used for substances, which are habit forming and are often abused, for example, narcotics like cocaine, morphine, heroine, marijuana, etc.

As you read in newspapers terms like illegal drug trade, drug trafficking, drug mafia, drug peddler are used to refer to illegal dealing with habit forming substances, referred to as drugs.

However the difference between drug and medicine is far from clear.

Intext Questions 35.1

1. Write a definition of medicines.

   .....

2. Most of the chemicals used in medicines are poisonous. Is this statement true or false?

   .....

3. What are pharmaceuticals?

   .....

4. Name the compound which is present in the plant sarpagandha and is responsible for reducing blood pressure.

   .....

35.2 Classification of Medicines

You may be familiar with some of the common medicines used for relieving pain, reducing fever or for treating common cold, etc. The number of medicines is very large therefore medicines are classified according to their action or use. Table 35.1 provides a list of some important classes of medicines. The terms like analgesics, antibiotics, antiseptics, etc. are common household words. Let us try to understand the meaning of this classification in a little more detail.

Table 35.1 : Some Important Classes of Medicines and their Action

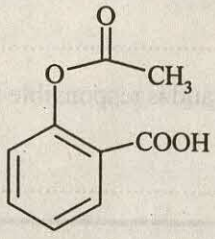
S.No.	Class	Action or Usage
1.	Antipyretics	Reduce body temperature
2.	Analgesics	Reduce pain
3.	Antimalarials	Used for treatment of malaria
4.	Germicides	Kill germs
5.	Antiseptics	Kill germs (can be safely used on living tissue)
6.	Disinfectant	Kill germs (cannot be used on living tissue)
7.	Antacids	Reduce acidity in stomach
8.	Anaesthetics	Loss of sensation
9.	Antimicrobials, Sulpha drugs and Antibiotics	Kill microorganisms
10.	Tranquilizers and hypnotics	Reduce anxiety and bring calmness
11.	Birth Control Medicines (Contraceptives)	Birth control

1. Antipyretics

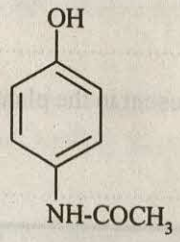
Antipyretics are the substances which are used to reduce body temperature or to control fever.

The word antipyretic is derived from pyro which means fire (means hot) anti means against. Thus antipyretic means it counteracts heat (high body temperature).

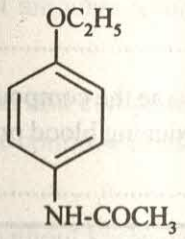
Aspirin, paracetamol and phenacetin are commonly used antipyretics. You get them in the market with different trade names like crocin, anacin, disprin, etc.



Aspirin



Paracetamol



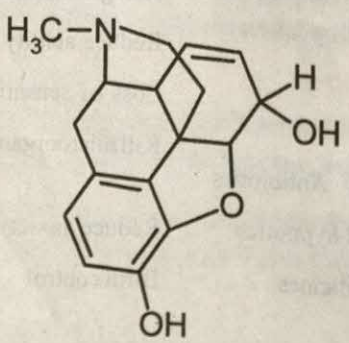
Phenacetin

Aspirin is the most popular antipyretic in use. It gets hydrolyzed in stomach and salicylic acid is released. Overdose and using it over a long time may cause side effects. It may cause bleeding in the stomach wall and even ulcers. Therefore, overdose and prolonged use should be avoided. However, calcium and sodium salts of aspirin are more soluble in water and are less harmful than aspirin.

2. Analgesics

Analgesics are the substances, that reduce pain which may be due to swelling of tissues, injury, inflammation or some other disorders. Analgesics are of two types, namely narcotic & non-narcotic.

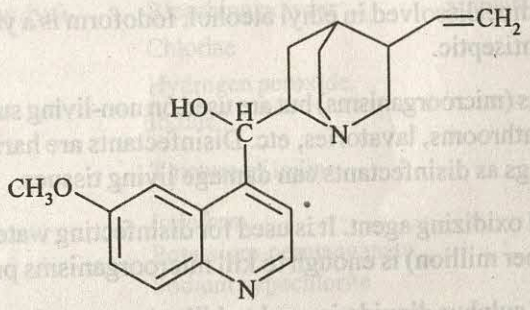
Narcotic analgesics are the ones which induce sleep and thus help to reduce the feeling of pain alkaloids present in opium, viz. morphine, codeine, etc. are common examples of narcotics. In higher doses these may cause unconsciousness. These are habit-forming and cause addiction. Due to addiction a person wants to have it regularly and in larger amounts. Such a person feels upset and uncomfortable if he doesnot get it. Narcotic analygesies do not induce sleep and are not habit forming. A common example of this type of narcotics is morphine.



Morphine

3. Antimalarials

Antimalarial medicines are used to treat malaria. Quinine and chloroquine are widely used antimalarials. Quinine is one of the earliest drugs, which was first obtained from the bark of a plant (cinchona) and later on synthesized in laboratories.



Quinine

Intext Questions 35.2

1. Give two examples of antipyretics.

   .....

2. Give one example of a narcotic type analgesic.

   .....

3. What is the difference between an antiseptic and disinfectant?

   .....

4. What are antacids? Name two chemicals commonly used as antacids.

   .....

5. What is the difference between local anaesthetic and general anaesthetic.

   .....

6. Define antibiotics. Give one example of an antibiotic.

   .....

4. Germicides, Disinfectant and Antiseptic

Germicides are the chemicals, which prevent growth of germs (microorganisms). Germicides are classified as antiseptic and disinfectant. Both kill microorganisms but the difference lies in the way we use them.

Antiseptics kill microorganisms and are safe to be used on living beings (tissues). Antiseptics are used on wounds, cuts or skin abrasions. These are used to dress wounds, etc. For example, iodoform (CHI_3), tincture of iodine, ethyl alcohol, a 0.2 percent aqueous solution of phenol and boric acid (H_3BO_3) are common antiseptics.

Some dyes have the ability to kill microorganisms. These dyes were the earliest compounds to be used as antiseptics. Examples are acriflavine (a yellow coloured dye), mercurochrome (a red coloured dye), methylene blue (a blue coloured dye). These dyes are still in use as antiseptics.

Iodine is a powerful antiseptic. It is used as tincture of iodine. Tincture of iodine is 2 to 3 percent solution of iodine dissolved in ethyl alcohol. Iodoform is a yellow coloured solid, which is used as an antiseptic.

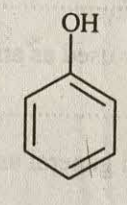
Disinfectants kill germs (microorganisms) but are used on non-living substances like surgical instruments, floors, bathrooms, lavatories, etc. Disinfectants are harsh and are not safe to be used on living beings as disinfectants can damage living tissues.

Chlorine is a powerful oxidizing agent. It is used for disinfecting water. A concentration of 0.2 to 0.4 ppm (parts per million) is enough to kill microorganisms present in water.

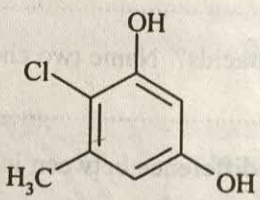
Low concentration of sulphur dioxide is used to kill microorganisms in jams, jellies and squashes. Thus it acts as a food preservative. Sulphur dioxide is used for fumigation in rooms, operation theaters, etc. to sterilize them. Bleaching powder ($CaOCl_2$), chlorine (Cl_2), mercuric chloride ($HgCl_2$), sodium hypochlorite (NaClO), sulphur dioxide (SO_2) etc. are other examples of disinfectants.

Is Phenol Antiseptic or Disinfectant?

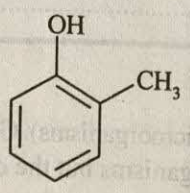
It is interesting to note that 0.2 percent aqueous solution of phenol is used as antiseptic by making. It is safe to be used on living tissues in low concentrations (less than 0.2 percent). If concentration of phenol is high then it can damage tissues. Therefore, at higher concentration (1 percent or more) phenol is used as disinfectant.



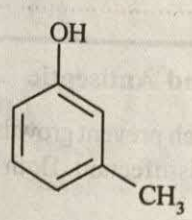
Phenol



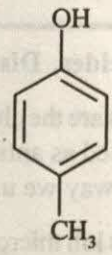
Chloro-xylenol



***o*-Cresol**



***m*-Cresol**



***p*-Cresol**

Most antiseptics and disinfectaints are powerful poisons (Table 35.2). They are able to kill microorganisms as they interfere with their metabolism. While some others are able to kill

microorganisms because of their powerful oxidizing or reducing nature (Table 35.2).

Table 35.2 : Nature of Some Important Antiseptics and Disinfectants

Poisons	Oxidising agents	Reducing agents
Dyes		
Acriflavine (a yellow dye)	Bleaching powder	Sulphur dioxide
Gentian violet	Chlorine	
Mercurochrome	Hydrogen peroxide	
Methylene blue	Iodine	
	Tincture of iodine	
Phenols	Iodoform	
	Potassium permanganate	
Phenol	Sodium hypochlorite	
Cresols		
Resorcinol		
Chloroxylenol		
Others		
Formaldehyde		
Boric acid		
Mercuric chloride		
Silver nitrate		

5. Antacids

Antacids are the medicines which neutralize the excess acid present in the stomach.

Stomach juice contains hydrochloric acid (HCl). This acid helps the process of digestion of food. Due to illness or anxiety or some other reasons more acid is produced in the stomach. The stomach juice becomes more acidic than necessary. This causes problems in digestion, bleeding in the lining of stomach or even ulcers. Some medicines are used to neutrialise the excess acid and correct the pH of the stomach fluid.

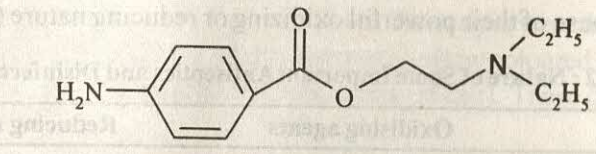
For example, sodium bicarbonate ($NaHCO_3$) or a suspension of magnesium hydroxide is used to neutralize excess of acid present in the stomach. Milk of magnesia contains magnesium hydroxide, 'ENO fruit salt' contains sodium bicarbonate which helps to neutralise excess acidity in the stomach juice. Medicine like digene, gelusil, used as an antacid contain magnesium hydroxide.

(E) Anaesthetics

Anaesthetics are substances, which cause loss of sensation over a small area (local) or loss of sensation of the whole body. There are two types of anaesthetics namely, local and general.

Local Anaesthetics

Local anaesthetics produce numbness or loss of sensation of pain, over a small area. Cocaine, procaine and xylocaine are used as local anaesthetic. These are useful for minor operations.



Procaine

General Anaesthetics

General anaesthetics cause unconsciousness and hence loss sensation of pain in the whole body.

General anaesthetics are used for carrying out major surgical operations. Some of the general anaesthetics are gases like nitrous oxide (also known as laughing gas). Some are low boiling ethers like diethyl ether, divinyl ether, etc. These are given to the patient by inhalation. On inhaling, these are absorbed through the lungs and make the person unconscious. Anaesthetics have made surgical operations less risky and less painful.

Some anaesthetics are given orally (by mouth), or by injections. Morphine and pathedine (these are the alkaloids obtained from opium) are given as injections or through oral route.

7. Antimicrobials

Many diseases are caused due to infection in the body by certain microorganisms (bacteria, fungus or viruses). Some examples of diseases caused by microbes are dysentry, pneumonia, typhoid, urinary tract infection, etc.

Antimicrobials are the chemicals, which are used to kill microorganisms (which has infected the body) without causing much damage to the body of the patient.

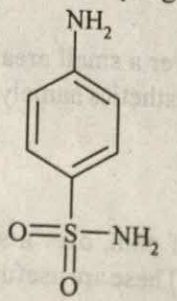
Thus an antimicrobial is a chemical, which is capable of curing diseases caused by various microbes.

An ideal antimicrobial should kill disease-causing microbe and should not have any harmful effect on the patient. In fact there may not be any such antimicrobial which is totally safe and without any side effect.

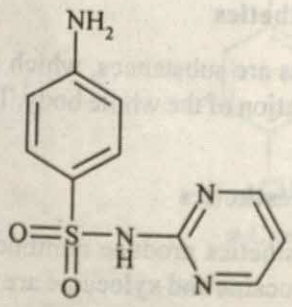
The most common antimicrobials available are the sulhpa drugs and antibiotics.

Sulpha Drugs

Sulpha drugs are a group of drugs, derived from sulphanilamide. All the sulpha drugs are synthesized in laboratories. Some of them have been very useful in treaing diseases caused by a variety of bacteria. Some of the important sulpha drugs are sulphacetamide, sulphadiazine and sulphaguanidine, etc.



Sulphanilamide



Sulphadiazine

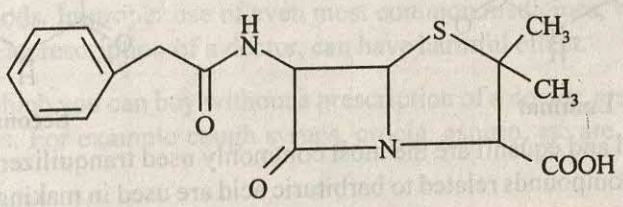
Sulpha drugs have been used for the treatment of pneumonia, sore throat, etc. These are less powerful than antibiotics. Therefore, now a days these have become less popular.

Antibiotics

Antibiotics are the metabolic products produced by some microorganisms (mould or fungi). They inhibit growth and even kill disease causing microorganisms (like bacteria, fungi, etc) by inhibiting their life processes. Therefore they are referred to as antibiotics (anti means against and biotic means life).

Penicillin was the first antibiotic to be discovered. Alexander Fleming isolated penicillin in 1929 from a mould *Pencillium notatum*. Penicillin has been used for the treating diseases caused by several bacteria. It has been effectively used for treatment of pneumonia, bronchitis, sore throat, abscesses, etc.

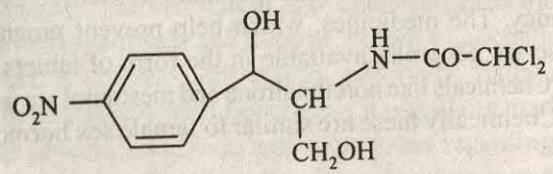
Later on attempts have been made to improve the quality of penicillin. It has led to the discovery of different varieties of penicillin. For example, Penicillin G (also known as benzyl penicillin), penicillin F, penicillin K are the more common varieties of penicillin.



Penicillin G (benzyl penicllin)

Ampicillin and amoxicillin are the semi-synthetic modifications of penicillin. In this case the metabolic product of mould is obtained and then some reactions are carried out to bring the desired changes in the antibiotic molecule to get ampicillin or amoxicillin.

Attempts are being made to discover better and better antibiotics. This search for finding better antibiotics is a never-ending process. Now a large number of antibiotics are available. Some examples are streptomycin and chloromycetin (chloroamphenicol) and tetracycline.



Chloroamphenicol

Streptomycin is used for the treatment of tuberculosis (TB). Chloromycetin is used for the treatment of typhoid. Tetracycline is used for the treatment of several diseases.

Broad-spectrum antibiotics are those antibiotics, which kill a wide range of disease-causing microorganisms.

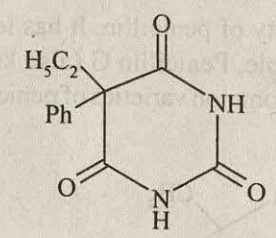
Broad-spectrum antibiotics can be used for the treatment of several diseases. For example, streptomycin, tetracycline and chloroamphenicol are broad-spectrum antibiotics. Narrow spectrum antibiotics are effective in the treatment of a few diseases.

Allergic Reactions of Antibiotics

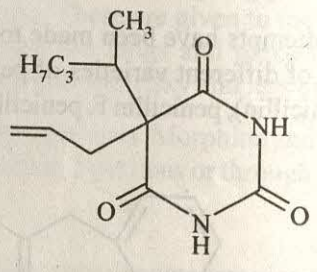
Some people may show allergic reactions to some antibiotics. These reactions may be mild like rashes appearing on the skin or may be very serious and can even be fatal. You might have observed that a doctor gives a small dose of antibiotic by injection and then waits for some time to watch if there is any unwanted reaction. If there is no adverse (bad) reaction, then only the doctor gives the full dose of the antibiotic.

8. Tranquilizers and Hypnotics

Tranquilizers and hypnotics are used to reduce anxiety, and they also make a person calm. Sleeping pills are made up of these compounds. Most of them are habit-forming. Their indiscriminate and over use should be avoided. Otherwise it may lead to addiction and many other complications,

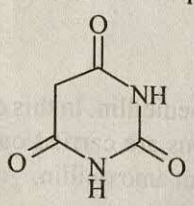


Luminal

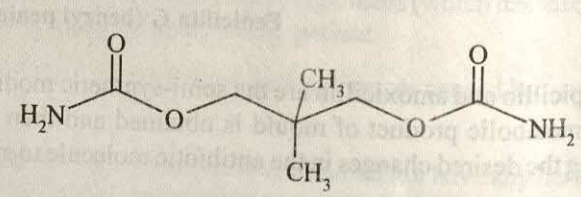


Seconal

Luminal, seconal and equanil are the most commonly used tranquilizers. Barbituric acid and some other compounds related to barbituric acid are used in making sleeping pills.



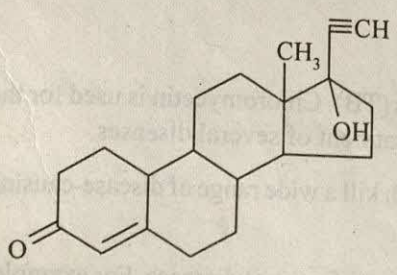
Barbituric acid



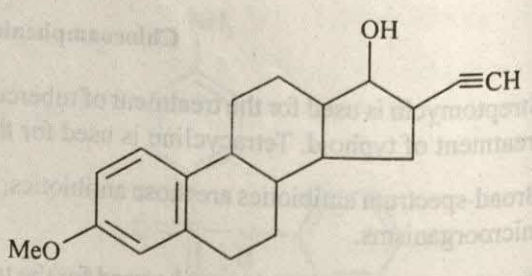
Equanil

9. Fertility Control Medicines

It is a concern of everyone to control human population. Medicines are available which help prevent pregnancy. The medicines, which help prevent pregnancy, are known as contraceptives. These are generally available in the form of tablets and are to be taken regularly by females. Chemicals like norethindrone and mestranol are used as contraceptives (birth control pills). Chemically these are similar to female sex hormones.



Norethindrone



Mestranol

The birth control pills may have some side effects in some cases. Therefore, the birth control pills should be used under the guidance of some expert.

35.3 Hazards of Self Medication

When medicines are taken by a patient without the advice of a qualified doctor, it is called self-mediation.

Self-medication is very harmful and a dangerous practice. One should never try self-medication. Some of the harmful effects are:

1. A medicine, which has worked well for some one, may not be good for you and can even cause some serious harm.
2. You may take a medicine in quantity more than necessary. It may be harmful for you.
3. You may take quantity less than necessary. The disease-causing microorganisms may gain resistance to the medicine and the medicine may become ineffective.

You should avoid self-medication. Without advice of a doctor avoid use of common medicines over prolong periods. Improper use of even most common medicines, which are readily available without a prescription of a doctor, can have harmful effect.

The medicines, which you can buy without a prescription of a doctor, are called over-the-counter medicines. For example cough syrups, crocin, aspirin, etc are over the counter medicines.

The medicines, which you can buy after showing a prescription of a qualified doctor, are known as scheduled drugs. Improper use of scheduled drugs is likely to cause more serious problems. Therefore, their sale is controlled and regulated by the government.

Most of good chemists do not sell scheduled medicines without a proper prescription. Some irresponsible chemists may sell such medicines without a prescription. It is not a good practice you should not encourage it.

35.4 Alternative Systems of Medicines

Allopathic system of medicine mostly make use of chemicals as medicines. It takes several years of testing and trials on animals and humans, before an allopathic medicine is made available in the market. It's effects, side-effects, efficiency, fixing recommended dose, etc. are extensively studied on scientific lines before it is sold in a market. Governments all over the world create several laws, rules and regulations regarding production, quality control, sale, etc. in the interest of public safety. The allopathic system is popularly known as the western system or the English system of medicine.

In addition to the allopathic system of medicine there are a large number of other systems of medicine which are used in different parts of the world. Some of them are Ayurvedic, Unani, Homeopathic, Chinese, Tibetan, conventional, tribal, traditional, etc. Some of these systems are more popular in a particular part of the world. Some are localised to a small area or used by a small group of people. In some cases there may not be any written record about the system of treatment and the knowledge is passed on by word of mouth from generation to generation.

Many of these systems are not popular over a large population. It may be due to lack of proper knowledge of the system or due to lack of adequate study of the alternative systems of medicine. There is an urgent need to extensively study all types of systems so as to make best use of knowledge for the benefit of mankind

Intext Questions 35.3

1. What is the use of tranquilizers and hypnotics?

   .....

2. Give one example of a tranquilizer.

   .....

3. What are contraceptives?

   .....

4. What are over the counter medicines?

   .....

What You Have Learnt

- Medicines are the chemicals or mixture of chemicals used for the prevention, cure, treatment, management of diseases and disorders or recovery of patients
- Medicines are obtained from plants or parts of plants or synthesized in laboratories.
- Medicines may contain only one chemical compound or it may be a mixture of several compounds.
- Drugs may be the crude mixtures and the identity of all the chemical components and their amount present in them may not be accurately known.
- Antipyretics are used to reduce body temperature for example aspirin and paracetamol.
- Analgesics reduce body pain for example aspirin and morphine.
- Antiseptics kill microorganisms and are safe to be used on a living tissue while disinfectants are used on inanimate objects.
- Aqueous solution (less than 0.2 percent) of phenol is used as an antiseptic. In higher concentrations phenol is used as a disinfectant.
- Antibiotics are the metabolic products produced by certain microorganisms which can kill some microorganisms. For example penicillin, streptomycin, tetracycline, etc.
- Broad spectrum antibiotics can kill several different microorganisms, therefore, can cure several diseases.
- Local anaesthetics cause numbness, loss of sensation of pain over a small area. General anaesthetics cause loss of sensation of the whole body.

- Self-medication is the use of medicines by patients without proper advice of a qualified doctor. It can be very harmful to the patient.
- In addition to the allopathic system of medicine there are several other alternative systems of medicine in use. Ayurvedic, Unani. Homeopathic, Chinese, Tibetan, conventional, tribal, traditional are some of the examples.

Terminal Exercise

1. How are medicines classified?
2. Who isolated the first antibiotic?
3. Name a medicine, which is used as analgesic as well as antipyretic.
4. What is a non-narcotic analgesic?
5. Why is 2.0 percent aqueous solution of phenol used as a disinfectant?
6. What do you understand by allergic reactions of antibiotics?
7. What are scheduled drugs?
8. Which medicines can you purchase without the prescription from a doctor?
9. What is self-medication? Describe some of its ill effects.
10. What are the alternate systems of medicine?

Answers to Intext Questions

35.1

1. Medicines are all those substances or formulations which are used for cure, treatment, prevention of diseases or disorders and recovery of a patient.
2. True
3. Pharmaceuticals are the chemicals which are used as medicines.
4. Reserpine

35.2

1. Aspirin and Paracetamol.
2. Morphine.
3. Disinfectants kill germs but can damage living tissues Anticeptics are safe for living tissues and yet kill germs.
4. Medicines used to neutralise excess acid in the stomach. Magnesium hydroxides and sodium carbonate.
5. Local anesthetics cause loss of sensation of pain over a small area while general anesthetics cause loss of concsiousness.

6. Metabolic products of certain microorganisms and can kill some other microorganisms. Penicilin is an example of antibiotic.

35.3

1. Tranquilizers and hypnotics are used to reduce anxiety and these also make a person calm.
2. luminal
3. Contraceptives are the medicines used for prevention of pregnancy.
4. Over-the-counter medicines are those which can be purchased without a prescription from a doctor.

Notes

36

BUILDING MATERIALS

In the first four lessons of this module you have learnt about petrochemicals and the synthetic organic chemicals that are derived from petroleum feedstock. In this lesson you will learn about materials produced in industry that are primarily inorganic in nature and are building materials.

Every creature needs a safe place to live in – be it a cave, a burrow or a nest and so on. The prehistoric man took shelter in caves to save himself from the beasts and the fury of nature. Since then different natural resources have been exploited, in native as well as in the modified forms, along with the synthetic materials to make living more comfortable. Today a large number of materials like, cement, steel, glass, ceramics, stone, timber, paints and varnishes etc. are used for making buildings and other structures that are strong, durable and safe. Chemistry has an important role in the development of these materials, their mode of action and newer applications. In this lesson you will learn about some of the building (or construction) materials in terms of their composition, preparation and applications.

Objectives

After reading this lesson you will be able to:

- define cement;
- list the raw materials used for the manufacture of Portland cement;
- discuss the process of setting of cement;
- describe different types of special cements and their applications;
- describe and differentiate between mortar, concrete and R.C.C;
- define glass;
- list the raw materials used for the manufacture of glass and outline their importance;
- describe the process of manufacture of glass;
- discuss general properties of glass;

- describe different types of glass and their uses;
- define the term, 'Ceramics';
- list different types of clay products and
- describe and distinguish between different types of clay products.

36.1 Cement

The word cement means 'to cohere or unite'. Cement can be identified as an inorganic material which when mixed with water gradually sets to give a hard mass. This is used to join (or cement) together bricks, stones, etc. to create different structures. Cement is in use since antiquity. The Egyptian pyramids and many of the ancient Greek structures were constructed by using some kind of cementing material.

There are different types of cements like, natural cement, Puzzolana cement, slag cement and Portland cement, etc. These differ in their composition, mode of preparation and applications. We shall discuss about the Portland cement which is currently the most commonly used cement in the construction works. In India manufacture of Portland cement started about a hundred years ago (1904) by South India Industries Ltd.. Today, Indian cement industry manufactures over 100 million tonnes of cement per year.

36.1.1 Manufacture of Portland Cement

Portland cement was invented in 1824 by calcinating (or burning) argillaceous limestone (limestone containing 20-40 % of clay). It was called as Portland cement because the concrete (a mixture of cement and gravel or sand) obtained from it resembled the building stone from Isle of Portland in England. Today many types of Portland cement with different compositions are available for different applications.

(a) **Raw Materials :** a number of raw materials are required for the manufacture of Portland cement. These can be broadly put into two categories :

(i) **Calcareous (rich in calcium) material :** like lime stone ($CaCO_3$), chalk etc. are the principal constituent of cement and need to be used in appropriate amounts. The excess of lime or its deficiency, both reduce the strength of the cement.

(ii) **Argillaceous material :** These are rich in silica and alumina for example, clay (a mixture of Al_2O_3, and SiO_2) , shale, slate or volcanic material etc. These impart strength to the cement and affect the setting properties of the cement.

In addition to the above, powdered coal or fuel oil and gypsum ($CaSO_4.2H_2O$) are also used in the manufacture of cement. Addition of gypsum controls the setting time of the cement. The amount of gypsum has to be carefully controlled because if it is present in more than required amounts it causes cracks.

(b) **Manufacturing process :** To prepare cement the raw materials are mixed in appropriate amounts, crushed to powder and then calcinated (burned or fired) There are two types of manufacturing processes **wet process** and **dry process** depending

on whether the mixing and grinding of raw materials is done in wet or in dry conditions.

(i) **Wet process** : in this method the raw materials are treated with water (about 35-40 % by mass) and then powdered in ball mills. These raw materials can be treated individually or in the form of a mixture. The paste like material so obtained is then sieved and powdered further if necessary. This is then passed through a rotary kiln (Fig. 36.1) for calcination.

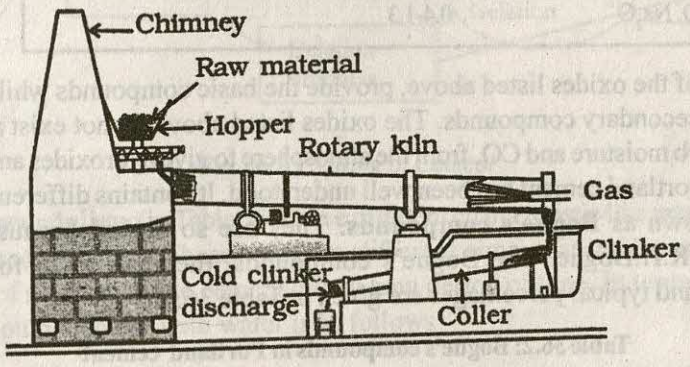


Fig. 36.1 : *Rotary kiln used in the manufacture of cement.*

The furnace consists of a slightly inclined long pipe that revolves slowly around its own axis. The mixture paste is fed into the long pipe through a hopper installed at the top of the pipe. As it moves down it meets the hot gases going upwards. In the high temperature of the kiln, the raw materials undergo a number of chemical reactions to form many new compounds. The mixture comes out of the kiln in the form of small greenish black or grey coloured hard balls known as **clinkers** which falls into a second pipe called cooler. These clinkers are then allowed to cool and powdered. To this powder a small amount (2-3%) of gypsum is added and powdered again to obtain cement.

(ii) **Dry method**: in this method the raw materials are mixed and powdered in ball mills. This is then placed into rotating panniers whose walls are fitted with water sprays. In the panniers the centrifugal force keeps the material in contact with the wall where it gets somewhat wet and takes the shape of small spheres. These are then passed through the rotary kiln as described above.

(c) Composition of cement

The Portland cement contains calcium aluminum silicates. It contains more than one compound. The approximate percentage of different elements present in Portland cement are expressed as their oxides (Table 36.1).

Table 36.1 : Approximate percentage composition of Portland cement

Oxide	Approximate percentage	Average percentage
CaO	60-67	64
SiO_2	17-25	22.5
Al_2O_3	3-8	6.5
Fe_2O_3	0.5-6.0	2.0
MgO	0.1-4.0	2.0
SO_3	1.0-3.0	1.5
K_2O, Na_2O	0.4-1.3	–

The first four of the oxides listed above, provide the basic compounds while the rest are referred to as secondary compounds. The oxides listed above do not exist as such. CaO and MgO absorb moisture and CO_2 from the atmosphere to give hydroxides and carbonates. Chemistry of Portland cement has been well understood. It contains different compounds which are known as **Bogue's compounds**. They are so named because they were identified by R.H.Bogue. The Bogue's compounds, their chemical formulae, and abbreviations and typical percentages are given in Table 36.2.

Table 36.2: Bogue's compounds in Portland cement

Name of the compound	Chemical formula*	Abbreviation	Typical percentage
Tricalcium Silicate	$3\,CaO\,SiO_2$	C_3S	54.1
Dicalcium Silicate	$2\,CaO\,SiO_2$	C_2S	16.6
Tricalcium Aluminate	$3\,CaO\,Al_2O_3$	C_3A	10.8
Tetracalcium Aluminoferrate	$4CaO.Al_2O_3\,Fe_2O_3$	C_4AF	9.1

70-80 % of cement is C_2S and C_3S.

In addition to the four compounds listed in Table 36.2, a number of some other compounds have been discovered in Portland cement but these four compounds are the most important. The amount of these compounds in a sample of cement can vary and determine the properties. of cement.

36.1.2 Setting and Hardening of Cement

In contact with water cement sets to a hard mass and this phenomenon is called setting of cement. The setting and hardening of cement is a process that takes a long time. A number of theories have been proposed for the setting of cement and there is a general agreement that it involves two important processes. These are **hydration** and **crystallisation**. Hydration is the initial stage when water is mixed with cement. It is followed by crystallization of different compounds.

The mixture of cement and water forms a **'cement paste'**. In this paste the constituents of cement get hydrated and form gel and crystalline products. Since the solubility of these

products in water is low, they cause the paste to get stiffened. (harden) This initial stiffening of the paste is called **setting of the cement.** The setting process is complete in about 25 hours. The paste then continues to harden over a long period of time. This process is called hardening and involves further gel formation and gradual crystallisation of the products of hydration. The process of **hardening** is almost complete in about a year, however this process continues for over a decade. The two processes are shown diagrammatically in Fig 36.2.

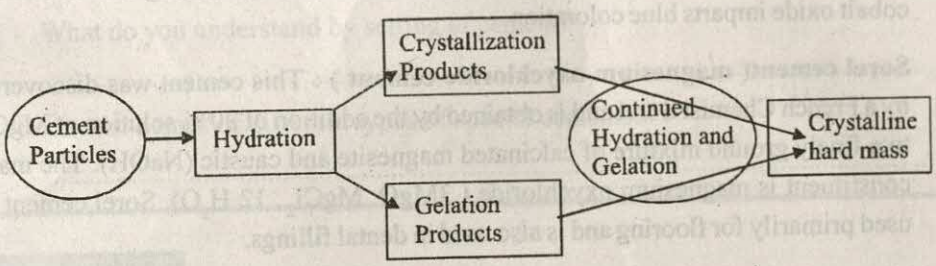


Fig 36.2 : *Setting of Cement*

Different compounds listed in Table 36.2 have different characteristic like rates of hydration, setting time and strength. These 'set' in different time span and contribute to the development of strength of the cement over a long period of time. In terms of chemistry, the first reaction of cement with water is as follows

$$C_3A + 6\,H_2O \longrightarrow C_3A \cdot 6H_2O$$

This reaction proceeds with the evolution of heat. After a few hours of contact with water, the following reaction starts

$$C_3S + H_2O \longrightarrow C_2S + C.\,H_2O$$

These processes cause the initial setting of the cement. In the second stage, i.e., hardening of cement involves the following reactions.

$$C_3A \cdot 6H_2O + C.\,H_2O + 6\,H_2O \longrightarrow C_4A \cdot 13\,H_2O$$

$$C_2S + n\,H_2O \longrightarrow C_2S\,.\,n\,H_2O$$

36.1.3 Special Cements

Portland cement also known as **normal setting** or **ordinary cement** is widely used for most of the construction activity like construction of buildings, roads, bridges and dams, etc.. However, it is unsuitable for application under corrosive conditions. Such applications require special characteristics in the cement. These have lead to the development of special cements. Some of these are given below :

(a) **High alumina cement** : this is prepared by fusing a mixture of lime stone and bauxite (an ore of aluminium containing some impurities of iron oxide, magnesium silicate, etc.) at high temperature. It has high rate of setting and hardening and can achieve full strength in about 24 h. It is also known as **quick setting** cement. It has superior chemical resistance so that it can be used safely, with sea water and water containing sulphates.

(b) **White Portland**: It is an expensive variety of normal setting Portland cement characterized by the absence of iron compounds. The absence of iron compounds gives it the whiteness. The **white cement** is expensive because its manufacture requires high purity of the raw materials viz. lime stone and clay. It finds applications in the manufacture of tiles and repairing of marble structures. White Portland cement has an added advantage that it can be mixed with different colouring materials (pigments) to give aesthetic applications. Chromium oxide gives it a green coloration, cobalt oxide imparts blue coloration.

(c) **Sorel cement(magnesium oxychloride cement)** : This cement was discovered by a French Chemist Sorel and is obtained by the addition of 20 % solution of $MgCl_2$ to a finely ground mixture of calcinated magnesite and caustic (NaOH). The main constituent is magnesium oxychloride ($3MgO.\ MgCl_2.\ 12\ H_2O$). Sorel cement is used primarily for flooring and is also used in dental fillings.

(d) **Water proof cement** : This is obtained by mixing water proof substances like, calcium or aluminium stearate during grinding while making Portland cement. Sometimes substances like soaps, waxes and bitumen etc. are also used to achieve water repelling properties.

36.1.4 Applications of Cement

Cement is generally not used as such, it is normally mixed with certain fillers or additives like sand, crushed stone, gravel, slag, etc. Depending on the nature of the filler or additive and the composition there are three broad types of mixtures. These are

(i) Mortar

(ii) Concrete and

(iii) Reinforced Concrete Construction (R.C.C)

(i) Mortar : It is obtained by adding water to a mixture of cement and sand. The resulting paste is called **cement-mortar.** Mortar finds applications in binding bricks and stones, etc. and also in plastering the walls.

(ii) Concrete : it is formed by making a mixture of cement and fine and coarse inert mineral aggregates like sand, coarse rock, stone, gravel or slag etc. The concrete can be put into any desired shape. Concrete finds applications in making roads, roofs, columns in the building, foundation works etc.

(iii) Reinforced Concrete Construction (R.C.C) : sometimes the constructed structure, say a bridge, has to take a lot of load. A plain concrete construction is not appropriate for such an application because concrete has low ability to withstand tension. In such cases, the structure is strengthened (or reinforced) by incorporating a net work of iron or steel rods which helps to take up load. This type of construction is called Reinforced Concrete Construction (R.C.C) and is used in the construction of bridges, arches, roofs girders, floor beams, etc.

Intext Question 36.1

1. What is Portland cement?

   .....

2. What are its main raw materials of Portland cement ?

   .....

3. What do you understand by setting of cement?

   .....

4. List the names of different types of special cements.

   .....

36.2 Glass

Your are familiar with glass and its common applications. Glass is defined as 'a rigid, amorphous transparent or translucent supercooled liquid'. It means that glass is not a solid but a rigid material that may allow light to pass through. Further, it is amorphous which means that it lacks regular three dimensional internal structure characteristic of crystalline solids. Glass has extremely high viscosity and normally does not set over a reasonably long period of time.

Glass is obtained by the fusion of sand, alkali metal carbonates alkaline earth carbonates and some other additives. We can not give it a particular chemical formula, however, glass can be roughly represented as $x\ M^{I}_{2}O \cdot y\ M^{II}O \cdot 6SiO_2$ where M^{I} = refers to an alkali metal like Na, K, etc. while M^{II}, indicates a bivalent metal like Ca, Pb, etc. Glass is a mixture of silicates of alkali and alkaline earth metals with excess of silica. Some verities of glasses may contain small amounts of Al_2O_3, Fe_2O_3 , etc. Some common variety of glasses are given in Table 36.3

Table 36.3 : Types of Glass

Type of glass	M^{I}	M^{II}	Approximate formula
Soda lime glass or Soda glass	Na	Ca	$Na_2O.CaO.6SiO_2$
Potash lead glass	K	Pb	$K_2O.PbO.6SiO_2$

Nowdays several formulations of glass are known. Silica, soda and lime are main constituents of all glasses. Let us learn about the various raw materials used in manufacture of glass and their roles.

36.2.1 Manufacture of Glass

A large variety of glasses are known today and these are prepared by varying the composition of the raw materials. The basic **raw materials** and their role in determining the properties of a glass are briefly outlined below :

(a) Raw materials

(i) Sand It is the source of silica.- the major component of glass. The sand used for manufacture of glass must be almost pure quartz containing about 99.1-99.7 % SiO_2. The sand particles should be uniform and of moderate size. Larger particles are slow to react while very fine particles cause violent reaction.

(ii) Alkali metal compounds: (Na_2CO_3, K_2CO_3, $NaNO_3$, KNO_3, Na_2SO_4). These are the sources of Na_2O (in soda glass) and K_2O (in hard glass).

(iii) Alkaline earth compounds: (CaO, $CaCO_3$ and $BaCO_3$). These are provided by lime stone and burnt lime from dolomite ($CaCO_3$ $MgCO_3$). Dolomite also provides MgO which helps in controlling the physical properties of glass. Alkaline Earth compounds contribute towards the high refractive index of glass.

(iv) Heavy metal oxides (ZnO, PbO, Pb_2O_4 and Pb_3O_4). Litharge (PbO) or red lead (Pb_3O_4) are used as a source of lead in flint glass or crystal glass. It provides lusture and high refractive index to the glass.

(v) Feldspar is a cheap source of Al_2O_3. Feldspars have a general formula $M^I_2O.Al_2O_3.6SiO_2$ where M^I represents Na or K or both. Therefore, feldspar has an added advantage as it provides Na_2O, K_2O and silica also. Alumina (Al_2O_3) makes glass resistant to sudden changes in temperature.

(vi) Borax is a minor component and is a source of boron oxide (B_2O_3) and Na_2O. Borax reduces the coefficient of expansion of glass and increases its fusibility, chemical durability and refinement.

(vii) Cullets or pieces of broken glass are generally added to the raw material to increase the fusibility of the glass produced from it. In other words it lowers the temperature of fusion so that we can manufacture glass at a lower temperature. The cullets may contribute from 10% to 80% of the raw material and thus provide a good way of utilising the waste glass.

(viii) Besides the above mentioned raw materials certain metallic oxides are also added to impart a colour (if desired) to the glass. Some of the principal glass colorants are given in Table 36.4 .

Table 36.4 : Some common glass colorants

Colorant	Formula	Colour imparted
Oxides of iron	FeO, Fe_2O_3	Light green or bottle green
Chromium compounds	Cr_2O_3, K_2CrO_4	Green tending to yellow
Cobalt oxide	CoO	Blue
Cadmium sulphate	$CdSO_4$	Yellow
Gold powder	Colloidal Au	Shades of ruby

(b) Manufacturing Process: The raw materials including the cullets are powdered in a grinding mill and mixed in proper proportion. This powder is then fused in an open or covered furnace. Certain decolorants like MnO, etc., are added and the heating is

continued till the evolution of gases stops. The coloring material is added at this stage and the heating is continued till a homogenous mass is obtained. It is then gradually cooled to a certain degree of plasticity so that it can be handled easily. The glass so obtained is called **mother glass**. It is then blown or moulded to get the desired shape. The articles are then cooled slowly. This process is called **annealing.**The finished glass product is then obtained after processes like cleaning, cutting , grinding and polishing ,etc.

36.2.2 Properties of Glass

- It is amorphous in nature, having low range of internal order.
- It does not have a sharp melting point. On heating glass gradually becomes softer and softer and eventually starts flowing.
- On cooling, the hot liquid gradually cools to a viscous liquid which can then be transformed into articles of desired shape.
- It may be transparent or translucent.
- It is quite inert and is not readily affected by ordinary chemicals except hydrogen fluoride and some alkalis.
- It has high compressor strength It lacks ordered internal structure.
- It is an insulator of heat and electricity.

36.2.3 Types of Glasses

Commercialy glasses are available in a wide variety. These are used for diverse applications from simple window pane to bullet proof glass. Some types of glasses and their uses are discussed below.

(i) **Soda glass or soft glass :** this is commonly used, low quality, cheap glass. It constitutes about 95% of all the glass manufactured and is prepared by fusing sand (silica), calcium carbonate (lime stone) and soda ash (Na_2CO_3). The approximate composition is $Na_2O.CaO.6SiO_2$. It contain 70 – 74 % SiO_2, 8 to 13% CaO and 13 – 18% Na_2O. About 2% of Al_2O_3 may be present as impurity. It is called soft glass because it soften at a relatively lower temperature. The soda glass also finds application in making electric bulbs, window panes, bottles, jars, etc.

(ii) **Lead Glass or flint glass:** is prepared by fusing litharge (PbO), potassium carbonate, soda ash, lime stone and silica in proper proportions. The approximate composition is $K_2O.PbO.6SiO_2$. It contains about 45% silica and variable amounts of lead oxide, Na_2O, K_2O and CaO. High lead-content glasses are used as shields against x-rays and γ-rays. These are used in the buildings in which x-ray and γ-ray scintillation units are installed. These may even be used in nuclear installations to protect from nuclear radiations. Besides, these applications, lead glass finds extensive use in making optical components like lenses, quality table ware (crystal ware), ornamental or artificial jewellery imitating artificial precious stones and electrical insulations, etc..

(iii) **Toughened (or tempered) glass:** this is not exactly a type of glass but a kind of treatment done to the glass article before annealing. The hot article is dipped in an hot oil both. The outer layer of the article shrinks and hardens whereas the internal layer is in a state of stress or tension. If the surface is broken, it shatters into many

pieces. This procedure is called **tempering** of glass. Such a glass is very strong and tough and can withstand higher mechanical and thermal shock. Such glasses are used in making automatic doors, large showcases. Toughened glass also finds application as wind shields of cars, trucks and aeroplanes.

(iv) **Laminated safety glass**: is obtained by pressing or bonding together two or three flat glass sheets having a thin layer of polyvinyl butyral plastic or vinyl acute resin and a bonding material (adhesive) between them. These may be cemented with the help of heat and pressure. The glass becomes tough on cooling and can withstand sudden changes in temperature and pressure. On breaking, the glass pieces do not fly off i.e. it is shatter proof. Such a glass is an ideal material to be used for entrance doors, sliding doors, sky lights, sloped looking windows of tall buildings, etc. These also find application as the wind screens of cars and automobiles. If several layers of glass are condensed together with alternating layer of vinyl resin we can get bullet proof glass

(v) **Insulated Glass:** it is prepared by entrapping insulating materials like anhydrous (or dry) air between two panes of glass thermally sealed along the perimeter. Such glass modules are used in places where inside of the building is to be protected from the drastic climatic conditions outside. In extreme weather conditions a module containing three panes and two layers of insulation may be used. These modules keep the room cool during summer and warm in winters.

In addition to the above mentioned, a number of other types of glass are known that find applications in making tableware, chemical containers and apparatus, optical lenses, goggles, neon signs, cathode ray tubes and many more.

Intext Question 36.2

1. List different raw materials used in the manufacture of glass.

   .....

2. What is the chemical composition of soda glass?

   .....

3. What do you understand by tampering of glass?

   .....

4. Give two examples of substances used as colourants for glass.

   .....

36.3 Ceramics

The term ceramics originated from the Greek word, keramos meaning ' burnt stuff'. It refers to a broad class of chemically inorganic materials that are prepared by high temperature processes or are used at high temperatures. These are broadly grouped into following classes :

- Clay products
- Refractories

In this section we shall discuss about clay products.

Clay Products

The clay products are sub divided into the following types.

(i) **Structural clay products**: these contain iron oxide as one of the important constituents and are used for making bricks, terra cotta, sewer pipes and tiles, etc..

(ii) **White wares or white pottery :** these are prepared from **china clay** (or Kaoline) mixed with some fusible silicates. These include products like chinaware, porcelain stoneware and vitreous ware.

(iii) **Chemical stoneware:** these are prepared from refractory clays mixed with crushed stones and pottery, etc. which are then glazed. These are generally quite strong and non-porous products. These find applications in making sanitary fixtures like bath tubs, wash basins, sinks and drainage pipes, etc.

Before proceeding with the details of these clay products let us learn about clay.

36.3.1 What is Clay?

Geographically, clays are the products obtained by the disintegration of rocks over long periods of time due to the effects of weather. These consist mainly of aluminium silicates along with other substances like, mica, quartz and sand, etc. some of the common clays and their chemical formulae are :

(i) Beidellite $Al_2O_3.2SiO_2.H_2O$

(ii) Kaolinite $Al_2O_3.2SiO_2.2H_2O$

(iii) Halloysite $Al_2O_3.2SiO_2.3H_2O$

These differ only in terms of the number of water molecules of hydration. Clays have an important property called plasticity because of which on mixing with water these form a plastic like mass which can be easily moulded into desired shape. You would have observed pottery makers turning clays into various shapes. The wet clay has sufficient rigidity so that it does not get deformed on standing.

36.3.2 Structural Clay Products

The structural clay products like bricks and tiles are prepared from common clay containing iron oxide and other impurities.

(i) Bricks: these are one of the oldest and extensively used construction material. These are cheap, locally available (other than on hilly areas) and have good strength. The main raw materials used for preparing bricks are clay (alumina) and sand (silica). Small amounts of lime (to reduce shrinkage and give strength) and iron oxide (to help in the fusion of the brick particles and for giving colour to the bricks) are also added. Manufacture of bricks involves the following steps:

- Kneading of clay with water till homogenous
- Moulding and drying of bricks
- Baking of dry bricks

Now a days bricks are being prepared from fly ash- the waste product of thermal power stations.

(ii) Tiles: these are prepared from better quality clay (free from pebbles, grit and other impurities) and are used in flooring, making pavements and roofs, etc.. Superior quality tiles are used for decorative purposes. Finely ground mixture of glass and pottery are also added to the clay while preparing tiles, this provides strength to the tiles.

36.3.3 Whitewares and White Pottery

These are clay products having white or pale-cream colour. Whitewares are prepared from china clay, feldspar ($K_2O.\ Al_2O_3\ SiO_2.$) and sand or flint(SiO_2). These are used in varying amounts to get different products. The raw materials contain none or negligible amounts of iron oxides.

To prepare whitewares the raw materials are ground to a fine powder and mixed with water. The wet clay is moulded into desired shape, dried, baked and glazed. During glazing the pores of the clay are plugged (closed) so as to make it water proof and shining. Glazing is done in a number of ways depending on requirement. Glazing materials used are glass forming materials like quartz, feldspar, lead and boro-silicates, etc. along with some coloring components. These are mixed with water to form a colloidal solution (called slip-glaze). The ware to be glazed is removed from the furnace and dipped into glaze-slip and continued to bake at high temperature. The glaze material fuses and fills the pores and provides a glossy surface to the ware.

36.3.4 Chemical Stoneware

As the name suggests, the stonewares are quite strong like stone. These are obtained by heating the raw materials at high temperature. A typical stoneware can be prepared by grinding a mixture of clay, kaoline, feldspar, and sand. The plastic like mass so obtained is moulded into the desired shape. The shaped articles are dried and heated at about 1273 K. These are then salt glazed at 1373 K. In salt glazing the hot article is sprinkled with sodium chloride and heated at high temperature. Sodium chloride vapourises and reacts with the ware producing sodium aluminium silicate. This is highly fusible and fills the pores on the surface of the article. This glazing treatment makes the article impermeable to liquids.

The chemical stonewares have low absorption power, high density and chemical resistance. These differ from the whitewares in terms of their colour. The stonewares are used in making sanitary fixtures like bath tubs, wash basins, sinks and drainage pipes, etc.

Intext Question 36.3

1. What are ceramics?

.....

Notes

2. What are clay products? How are these classified?

.....

3. List the raw materials used to prepare white wares.

.....

4. List different uses of chemical stone wares.

.....

What You Have Learnt

- Cement is an inorganic material which when mixed with water gradually sets to give a hard mass and can be used to join together bricks, stones, etc.
- There are different types of cement that differ in their composition , mode of preparation and applications. Of these, Portland cement is currently the most commonly used cement .
- Portland cement contains a number of oxides which exist as complex compounds like, tricalcium silicate , dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrate, etc. These are called **Bogue's compounds.**
- Setting of cement involves two important processes hydration and crystallisation. These processes take long period of time.
- Cement is used in combination with a number of additives like sand, coarse rock, stone, gravel or slag, etc.. depending on the application. These combinations are called mortar or concrete depending on the additive. A concrete reinforced with steel is called R.C.C.
- Glass is 'a rigid amorphous transparent or translucent supercooled liquid' which lacks regular three dimensional internal structure and has extremely high viscosity.
- Glass can be roughly represented as $x\ M^{I}_{2}O\ .\ y\ M^{II}_{O}\ .\ 6SiO_2$ where M^{I} and M^{II} are alkali metal and bivalent metals respectively.
- For manufacturing glass, the raw materials like sand, feldspar, alkali metal and alkaline earth compounds, heavy metal oxides, etc. are mixed in proper proportion, powdered, and fused in a furnace.
- Commercial glasses are available in a wide variety. There are used for diverse applications from simple window panes to bullet proof glass etc.
- Ceramics refer to a broad class of chemically inorganic materials that are prepared by high temperature processes or are used at high temperatures and are classified as clay products, and refractories.
- Clay consists of a mixture of aluminosilicates differing in number of water of crystallisation.
- Clay products are classified into structural clay products (like bricks and tiles etc) , Whitewares and stonewares.

Terminal Exercise

1. Match the following

(i)	Mixing of water and cement leads to	Crystallisation
(ii)	Second stage of hardening of cement	Sorel cement
(iii)	Cement with good chemical resistance	Mortar
(iv)	Cement used in repairing marble	High alumnina cement
(v)	Cement used in dental fillings	White cement

2. Describe the process of manufacture of cement.
3. What are Bogue's compounds and what is their importance.
4. Discuss different applications of cement.
5. What is the composition of white cement ? Give some of its applications.
6. Differentiate between

(i) Mortar and concrete

(ii) Concrete and R.C.C

7. Describe the process of manufacture of glass.
8. List different raw materials used for the manufacture of bricks and indicate their role.
9. What do you understand by the term, 'glazing'? Why are certain clay products glazed?

Answers to Intext Questions

36.1

1. The Portland cement is the most commonly used cement. It contains a number of sliticates like calcium aluminio silicates.
2. Calcareous materials like limestone and chalk and argillaceous materials like, clay, shale or slate, etc. are the principal constituent of cement. In addition to these, powdered coal or fuel oil and gypsum ($CaSO4.2H_2O$) are also used.
3. Setting of cement involves two important processes called hydration and crystallisation. These processes take a long time. On mixing water and cement the constituents of the cement get hydrated and form gel and crystalline products. These cause the paste to stiffen and it is called setting of cement.
4. There are different types of cement with special properties. Some of the special cement are : high alumina cement, while Portland, sorel cement and water proof cement.

36.2

1. Sand, Alkali metal compounds, alkaline earth compounds, heavy metal oxides, borax & cullets.
2. Please refer to section 36.2.3
3. Please refer to 36.2.3
4. Oxides of iron and gold powder

36.3

1. Please refer to section 36.3
2. Please refer to section 36.3.1
3. China clay, feldspar and sand
4. Bath tubs, wash basins, sinks & drainage pipes.

SENIOR SECONDARY COURSE
CHEMISTRY
Student's Assignment – 7

Maximum Marks: 50 **Time : $1\frac{1}{2}$ Hours**

INSTRUCTIONS

- Answer all the questions on a separate sheet of paper.
- Give the following information on your answer sheet:
  - Name
  - Enrolment Number
  - Subject
  - Assignment Number
  - Address
- Get your assignment checked by the subject teacher at your study centre so that you get positive feedback about your performance.

Do not send your assignment to NIOS

1. (a) List two biotic components of environment.
   (b) What are secondary (anthropogenic) pollutants?
   (c) Name one harmful effect of CO as a pollutant.
   (d) Define surface water.
   (e) List two sources of ground water pollution.
   (f) Name the element that causes Minamata disease.
   (g) What is a heavy metal?
   (h) List two ways by which lead enters the human body.
   (i) List two ways (anthropogenic) by which ionizing radiations are exposed in the atmosphere.
   (j) Write names of monomers of terylene. $1 \times 10 = 10$
2. (a) Define pollution. List two sources of natural pollutants.
   (b) Write the sources and the effects of the following pollutants: (i) SO_2 (ii) Lead.
   (c) Define water pollution. What are the two basic factors responsible for water pollution.
   (d) What are the four man-made sources of water pollution?
   (e) Define eutrophication. How is it causes?
   (f) What are the three stages of water treatment. Explain any one stage.
   (g) List six sources by which environment is contaminated by heavy metal.
   (h) Why is it impossible for a nuclear reactor to blow up like a bomb? Explain.

(i) Differentiate acid dyes from basic dyes.

(j) Give two examples of bippolymers. (2 × 10 = 20)

3. (a) How can heavy metal be removed from rivers and sediments?

(b) List three properties of emulsion paints.

(c) Draw a diagram to show the sequence of steps leading to eutrophication of water body?

(d) Define green house effect. Name any four greenhouse gases and their sources. (3 × 4 = 12)

4. (a) Suggest four measures by which exposure of nuclear radiation can be reduced.

(b) What are the effects of ozone depletion? (4 × 2 = 8)

Notes

TERMS YOU SHOULD KNOW

Abiotic	:	Non living (physical) components of environment such as soil, water,
Acid precipitation	:	Pollutant gases such as SO_2,NO_x are washed out of atomophere and produce acid precipitation as rain of snow.
Acid rain	:	Rain with a pH below 5, containing pollutants such as SO_2, NO_x, hydrocarbons, O_3 and and amonium sulphate This rain changes the ecosystem and damages buildings.
Aerodic pathway	:	Chemical reactions occuringin an organism in the presence of oxygen.
Afforestation	:	Planation of many trees on a barren land.
Anaerobic bacteria	:	Bacteria capable of living in the absence of free oxygen.
Anaeroic pathway	:	Chemical ractionsoccuringin an organism in the absence of O_2.
Anthropogenic	:	Man made.
Autotrophs	:	Organisms manufacturing own food such as plants.
α-particles	:	Positively charged particles emitted by radioactive substances equivalent to helium atoms which have lost their electrons.
Aquatic life	:	Organisms living water.
Atmoshpheric pollutants	:	Unfavourable substances in air.
ATP	:	Adenosine triphosphate, biological energy.
Bioaccumulation	:	Accumulation of toxic substances (such as DDT) in the body of organisms.

Notes

Biogeochemical cycle : Cyclic transformation of certain essential chemical elements as they pass from soil and atomsphere through living components of ecosystem & eventually returned back to soil and atmosphere.

Biomagnification : Increased accumulation of toxicaubstances along the food pyramid.

Biosphere : Part of globe containing living organisms.

Biosyntheis : Synthesis of chemicals required by organisms.

Biotic : Living components of the environment e.g. plants, animals etc.

BOD : Biological (or Biochemical) Oxygen Demand. The amount in milligrams per litre of dissolved oxygen required by aerobic bacteria ot decompose organic matter in water solution.

β–particles : A charged particle equivalent to an electron if negative or positive emitted from the nucleus in radioactive decay of fission.

Bronchitis : Inflammation of the membrane lining the bronchial tubes.

Carbomino haemoglobin : A compound formed by the combination of CO_2 and haemoglobin in blood.

Carcinogenic : Cancer causing

Coagulation : Clotting or clumping.

Compaction : Fertile soil packed closely and firmly to form it a dense solid mass leaving no air space reducing to a barren piece of land.

Consumers : Animals which eat plants.

Coronary : Pertaining to heart.

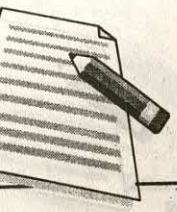
Notes

Glossary

Corrosion	:	Gradual eating away (degradation) through chemical action
Crust	:	Outer layers of the earth.
Decibel	:	Unit of loudness or measure of physical pressure extented by sound waves at a given point.
Defence proteins	:	Antibodies which are responsible for immunity and resistance against foreign substances entering body.
Deforestation	:	Cutting down trees in a forest.
Dry deposition	:	Acid gases as SO_2, NO_x have effects as dry gases.
Ecosystem	:	A biological community and the physical environment a associated with it.
Effluent	:	Refuse discharged from factories.
Emphy sema	:	Abnormal distention of an organ or part of the body esecially lungs with air or any other gas.
Environment	:	Sum total of external influences acting on an organism.
Eutrophication	:	Process of aging of abody of water due to growth of algae. Algae flourish and die and their decay depletes water of its dissolved oxygen content.
Food chain	:	Sequence of organisms in which each is food of a later member of the sequence.
Fossil fuel	:	Coal, petroleumand gases or liquids derived therefrom.
Flocculants	:	Chemical agents that cause clumping of undesirable solids in suspension and then precipitation of these solids.

Notes

Fragile	:	Delicate, easily broken.
Geological time	:	Chronoligical age of earth.
Global warning	:	Rise in the normal temperature of earth.
Green house effect	:	Warming of lower layers of atmosphere due to absorption of short wave length solar radiations.
Ground water	:	Water below the earth's surface.
Half life	:	Time required for and unstable element or nuclide to lose one half of its radioactive intensity in the form of a α, β or γ radiation.
Halons	:	Halo carbons - C_xF_x,C_xBr_x used as antifire agents.
Urbanisation	:	City living.
Incubation	:	Keeping at a particular temperature.
Ionision radiation	:	Radiation having enough energy to cause ionisation and produce ions in a system.
Leaching	:	Process by which organic matter and mineral salts are washed out of a layer of soil by percolating rain water.
Marshes	:	A soft and wet area which suffers from poor drainage and frequent water logging.
Membrane transport	:	Movement of molecules acrosscell membranes.
Metabolism	:	Constructive and destructive chemical changes occuring in the living organism.
Methaehaemoglobinemia	:	Presence of methaemoglobin whichis more stable thanoxyhaemoglobin. Excessive leyels of nitrates in water cause it. Babies suffering from methaemoglobinemia are called blue babies.



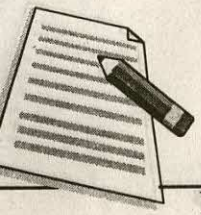
Notes

Glossary

Microbe	:	A microoorganism such as bacterium.
Mitochondria	:	Cell organelles responsible cellular respiration.
Methanogenic (methanotrophs):		Bacteria which produce CH_4 throught their biological activty.
Nitrifers	:	Bacteria which convert ammonia into nitrities and nitrites into nitrates.
Non-biodegradable	:	Whichcannot be broken down by micro organism.
Nuclear reactor	:	An assembly in which chain reaction is caused to take place in controlled manner.
Nuclear fusion	:	A thermonuclear reactionin which positively charged hydrogen nuclei (protons) unite of fuse to from heliun with evolution of energy.
Oxygen depletion	:	Reduction in the oxygen content.
Oil slick	:	A phenomenon caused by activities of ships of effluents from shore installations. Less volatil components of oil combine with sea water and form dark viscous slick which to sea bed or floats of as tar.
Organic Matter	:	Substance belonging to organisms.
Ozone hole	:	A gap in the ozone layer in the atmosphere lying between 10 to 50 km. above the surface of the earth Ozone hole develops over antartica each spring and size of hole corresponds to the concentration of CFC in polar atmosphere.
PAN	:	Peroxyacyl nitrates found in photochemical smog.
Particulate matter	:	Composed of distinct particles
Pesticide	:	Chemicals used for killing pests such as DDT.

Notes

Photochemical oxidants	:	Ozone, PAN, aldehydes etc. produced by chemical reaction in the presence of light between usaturated hydrocarbons and nitrogen oxides
Photochemical smog	:	A complex mixture of undesirable substances formed by the action of sunligh on urban atmosphere polluted with automobile emission
Photosynthesis	:	Synthesis of starct from CO_2 and H_2O in the presence of light and chlorophyll.
Phytotoxic	:	Harmful to plants
Plankton	:	Organisms floating in water.
Producers	:	Plants which manufacture food for themselves and eaten by other organisms.
Radioactive fallout	:	Settling of air borne particles of radioactive dust and other material resulting from nuclear explosion on the ground.
Radionuclide	:	Unstable nuclide undergoing spontaneous radioactive tranformation with emission of particle or phton.
Respiration	:	Process of taking in oxygen laden air and removing CO_2 laden air.
Stratosphere	:	Region of upper atmosphere extending from troposphere to about 15 km above earth.
Solar energy	:	Energy derived from sun.
Surface water	:	Water flowing in streams and over the ground surface.
Swamps	:	Wet muddy areas.
Tailing X-ray	:	Analysis of portionns of washed ore regarded as too poor to be treated further. Also called debris.



Notes

Glossary

Thermal	:	Pertaining to heat.
Fluorsis	:	Poisoning by excessive use of fluorides.
Toxic	:	Poisonous.
Troposphere	:	Inner layer of the atmosphere where cloud formatic occur.
Vehicular combustion	:	Burning of fuel in a vehicle such as petrol in order drive it.
γ-Ray	:	High frequency, highly penetrant electro-magnetic radiation of short wave length emitted from the nuclear of a radioactive atom.

Feed back on Lessons

Lesson No.	Lesson Name	Content			Language		Illusttrations		What You Have Learnt	
		Difficult	Interesting	Confusing	Simple	Complex	Useful	Not useful	Very helpful	Not helpful
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FUNDAMENTAL DUTIES
Part IVA (Article 51 A)

It shall be the duty of every citizen of India-

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forest, lake, rivers and wild life, and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excellence in all spheres of individual and collective activity so that nation constantly rises to higher levels of endeavour and achievement.

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The learners can have an access to NIOS web-site at the following address:

http:/www.nos.org & nios.ac.in

Clicking the site address will bring the user to NIOS home page that will further guide them to visit different information pages of NIOS. NIOS is also developing a school network through Internet known as Indian Open Schooling Network (IOSN). The network will provide a common communication platform for learners and educators. NIOS is offering Certificate in Computer Applications (CCA) through selected AVI. This course is also offered through Internet on NIOS Web-Site.

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